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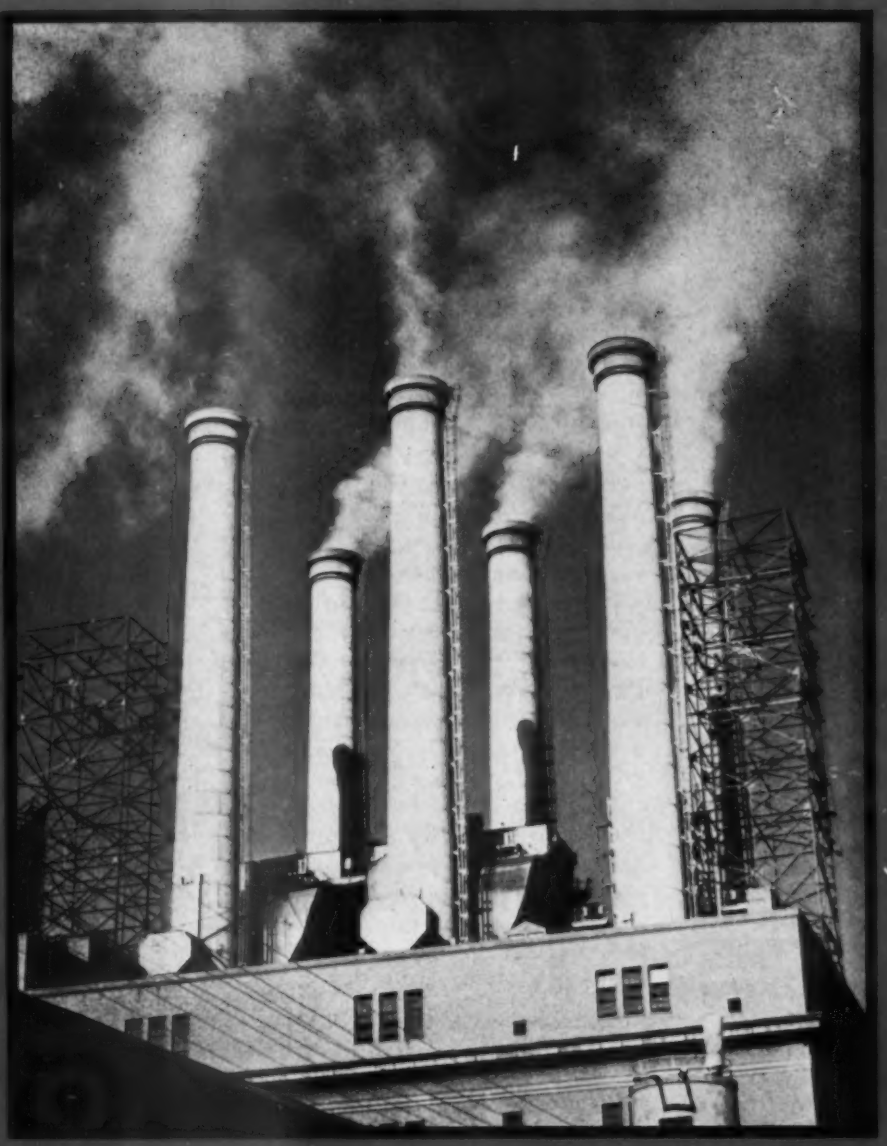
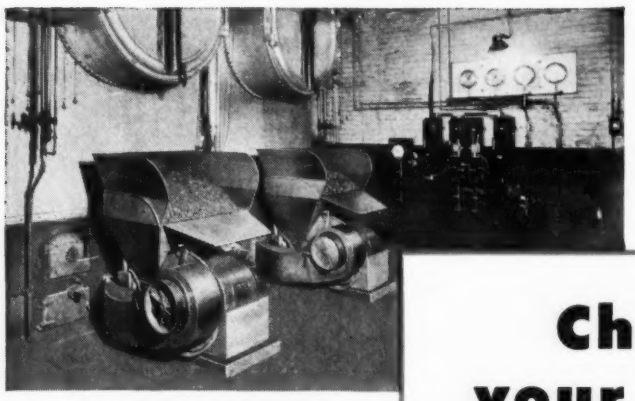
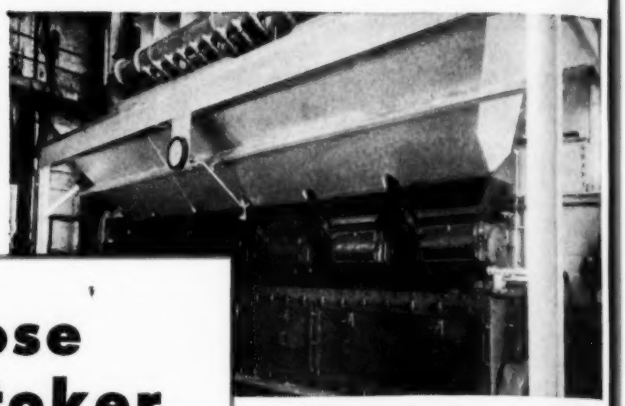


Waterside No. 1 Completes Its Topping Program ▶

Model Test Analysis of Steam Piping ▶





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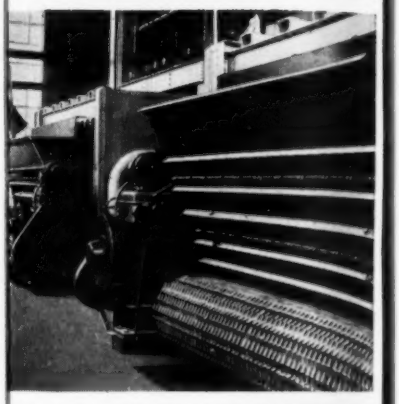

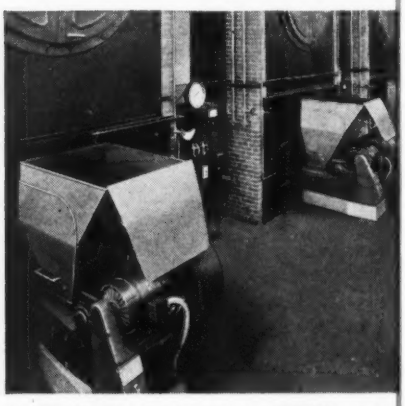

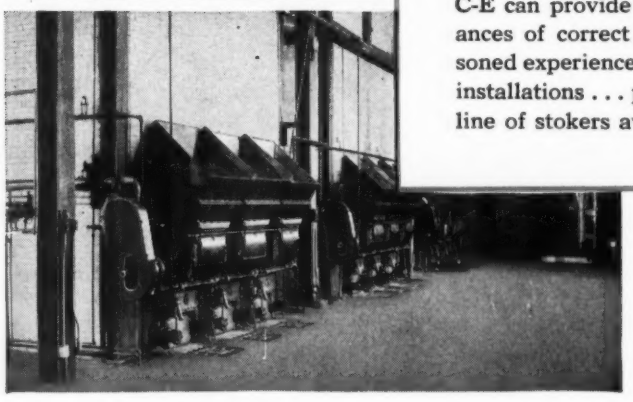

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWENTY NUMBER TEN

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FOR APRIL 1949

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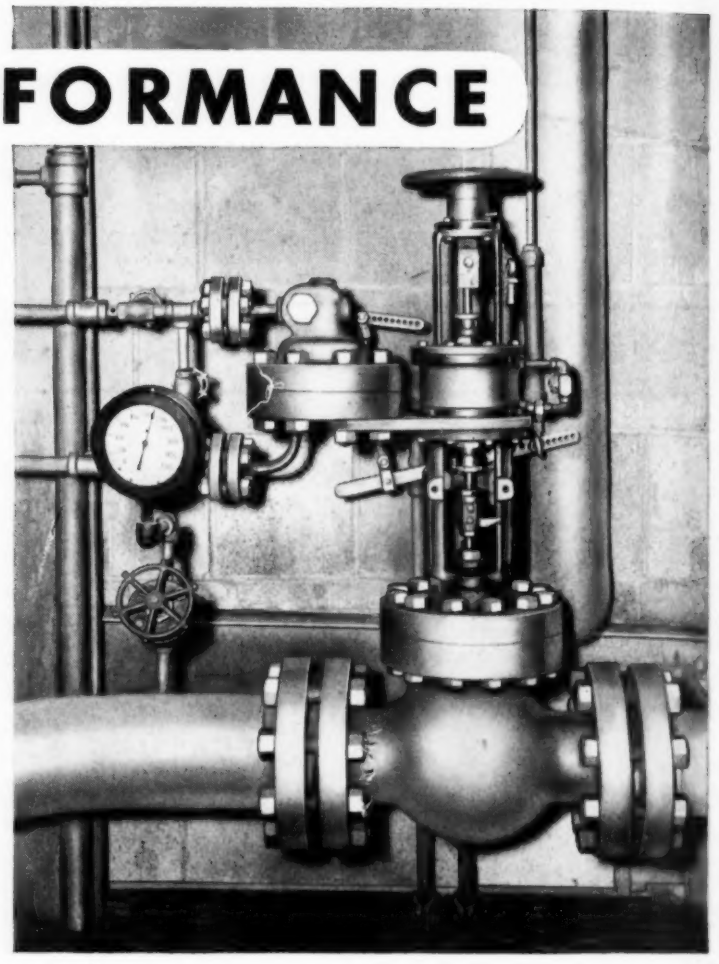

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EDITORIAL

Unit Boiler-Turbine Plants

The great majority of recent central stations have been designed as single boiler-single turbine installations. This tendency reflects the improved availability and reliability of steam generating equipment, as well as the inherent advantages of this type of station arrangement.

Among the advantages of unit boiler-turbine plants are fewer valves and simplified piping. These, in turn, permit less complex operating procedures and a higher degree of centralized control.

Operating experiences to date have demonstrated that confidence in the reliability of the unit boiler-turbine plant has been warranted. This type of installation has also more than paid its way economically, both in reduced first cost and in lower operating expense. With the renewed interest now shown in the reheat cycle, the tendency toward unit boiler-turbine installations may be expected to continue, as many of the advantagesof this cycle would be offset by the complications of control and operation introduced by having more than one boiler per turbine.

Outdoor Construction on the Increase

When semi-outdoor electric generating stations were introduced in the early thirties, they were generally looked upon, despite one or two exceptions, as adapted to the warmer sections of the country. In fact, there was much skepticism as to whether this type of construction was at all practicable for northern climates. One factor was the belief that coal handling in freezing weather would present a serious problem; and another was anticipated inconvenience to operating personnel. Hence for some years such plants were located mostly in the South or Southwest with oil or gas as fuel and were confined to moderate capacities.

Experience showed performance to be comparable with that of fully housed plants, and in some cases there was a reduction in operating personnel due to the more compact and simpler arrangement. Also, maintenance was reported as satisfactory and protective measures were evolved to take care of coal handling in the few coal-burning plants located in a cold climate.

The general plan has been to place the steam generating equipment and related auxiliaries out-of-doors and to provide a simple housing for the turbine-generators and the control equipment, thus protecting operators from the weather; although in rare cases the turbine-generators have also been installed out-of-doors. Switching equipment was so located long before the advent of the semi-outdoor plant.

Yet, conservatism on the part of many designers and their inherent attachment to architectural features retarded the more widespread pre-war adoption of this type of plant. This was particularly true of locations in or near metropolitan areas.

However, with rising costs of steel and labor, and saving in erection time as most important factors, it is not surprising to find a number of post-war plants in the North embodying the semi-outdoor arrangement. This applies to large stations as well as those of medium size, and to pulverized coal firing as well as gas and oil. Overall initial savings of as much as seven to ten dollars per kilowatt have been claimed, which seems plausible in view of present-day costs. This trend appears to be on the increase.

Looking Back Sixty Years

A COMBUSTION reader has brought to our attention an old volume issued in 1886. This is a directory of Scranton, Pa., by W. S. Webb, containing, in addition to the usual list of citizens, business firms and data on local industries, considerable miscellaneous information of general interest. Inasmuch as Scranton is located in a coal-producing region it is logical to find considerable space devoted to the subject of fuels, both solid and gaseous. In this connection it is interesting to compare the predictions of more than sixty years ago with what has since transpired.

A number of pages are devoted to pulverized coal, particularly the early experiments by Whelpley and Stover, and encouraging prospects are seen for pulverized anthracite. Notwithstanding this, gas is portrayed as "the fuel of the future"—not natural gas, whose "life is short," but manufactured gas. The observation is made that "the days of solid fuels for many purposes are numbered and we shall soon usher in a new candidate for public favor, and transform all the solid fuels into gaseous before using."

Further, we find the statement that "It is by no means an unreasonable expectation that the producer may be placed in the mine, and the gas piped to the surface and distributed."

While subsequent trends have deviated considerably from these predictions, that concerning the production of gas directly from coal in the mine may be borne out by the results of the experiments now being carried out at Gorgas, Ala.

Waterside No. 1 Completes Its Topping Program Part I—Steam Generation

By R. T. ROBERTS, Division Engineer,
Consolidated Edison Company of New York

Fifty-three old, low-pressure boilers have been replaced by two large steam generating units, each capable of supplying 1,000,000 lb of steam continuously at 1600 psig and 950 F to two 50,000-kw topping turbines which exhaust to the low-pressure mains supplying two new 60,000-kw machines. The present article describes the boiler plant in detail and a subsequent article will deal with the turbines and auxiliaries.

WATERSIDE STATION of the Consolidated Edison Company of New York, Inc., actually consists of two stations: Waterside No. 1 occupying the block from East 38th to East 39th Street, and Waterside No. 2 the block from East 39th Street to East 40th Street. The stations face First Avenue on the west and the East River Drive on the east, with overhead bridges to the coal and ash handling facilities on the water front and tunnels under the Drive for water. Waterside No. 1, to the south, is the older of the two stations.

Some years ago, the steam mains of the two stations, then both operating at 200 psig, were connected by overhead lines across East 39th Street and piping for the return of condensate was installed in a tunnel under the street. Bridges for physical passage and for coal conveyors completed the unification, so that the two were operated as substantially a single station.

Later, the ninety-two boilers in Waterside No. 2 were removed and eight topping boilers, supplying steam to four topping turbines, were installed. Low-pressure steam exhausted from the topping turbines was used to supplement that generated by the low-pressure boilers

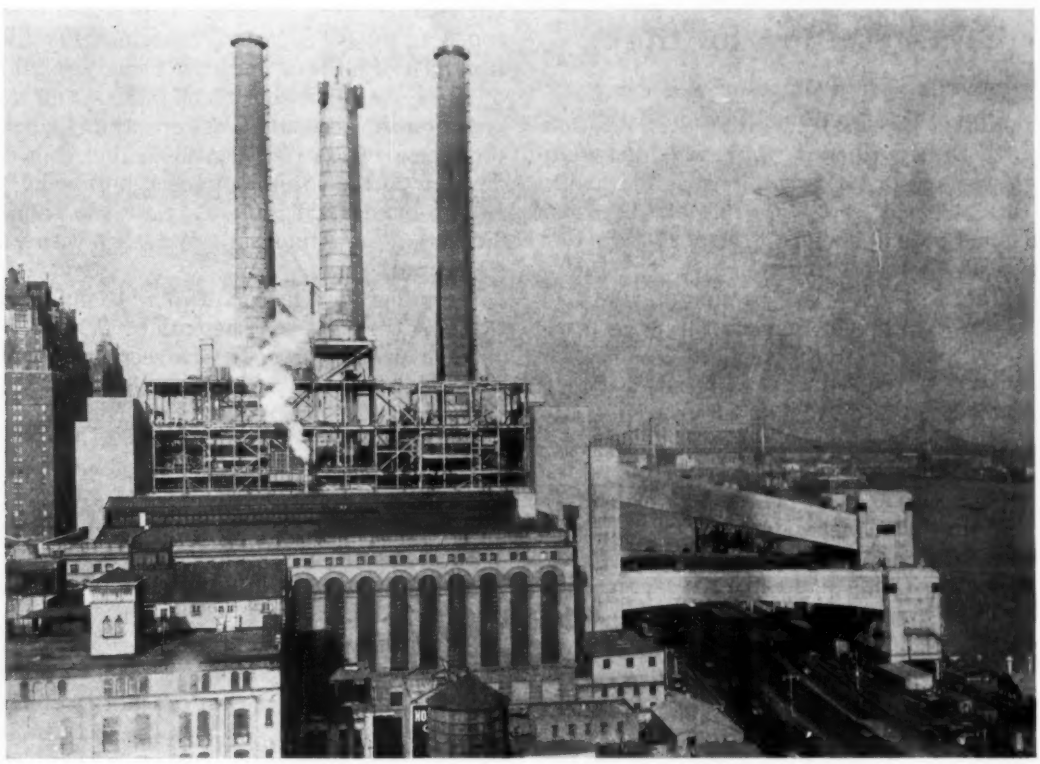

Fig. 1—General view of boiler house and stack erection

in Waterside No. 1. The two steps in the Waterside No. 2 topping program were described in several publications at that time, among them COMBUSTION of September 1937 and March 1942.

In 1945 the topping program at Waterside No. 1 was started. This renovation was somewhat more extensive than required by Waterside No. 2, as it practically required unroofing the entire boiler room as well as completely rebuilding the west end, while at Waterside No. 2, some of the overhead bunkers and the roof, with the exception of the stacks were not substantially changed (see Figs. 1, 2, and 3).

In the turbine room, however, the topping program was preceded by the installation of two new 60,000-kw low-pressure turbine-generators requiring the removal of three 20,000-kw existing vertical units. These new machines are fed from the low-pressure system, which receives its steam from the topping units in Waterside No. 2. The two new 50,000-kw topping turbines in Waterside No. 1 are located in the boiler room; No. 8 unit to the west of boiler No. 80 and No. 9 unit to the east of boiler No. 90, in order to reduce the overall length of the high pressure steam leads

The program was authorized as two projects. The first topping boiler was purchased and work started. This contemplated the removal of thirty-seven old boilers and their auxiliary equipment, together with the relocation of other auxiliaries to the eastern area of the boiler house, to serve the remaining boilers.

Growing demand for more capacity, however, required the purchase of the second boiler and turbine, and the dismantling of the remaining sixteen low-pressure boilers and their auxiliary equipment. The two projects were then combined and proceeded as one installation.

In choosing the initial steam conditions and cycles for study, a number of interrelated factors were considered. The higher the initial pressure and temperature, the greater the capacity in the topping unit for a given exhaust pressure. The pressure should be made as high as consistent with adequate steam temperature for the low-pressure turbines, with due consideration given to cost of boiler and other pressure parts.

With a fixed initial temperature to the topping unit, increasing initial pressure reduces the temperature in the exhaust, which was limited by the low-pressure turbines at about 200 psi and 500 F. Conversely, reducing the pressure raises the exhaust temperature. It was desired to maintain about 100 deg of superheat or above in the steam to the low-pressure turbines since maintenance becomes excessive due to water erosion in the lower stages when sufficient superheat is not maintained.

Higher pressure with reheat was considered but proved unattractive. One typical case of a reheat cycle is shown in Scheme F_2 of the following tabulation. Since the steam temperature to the low-pressure turbines was limited to about 500 F, the economy of reheat was limited, while the major portion of the reheat investment would be required.

At the time of making this study the Company, as well as others, had operating experience with 950 F steam. There was, however, no experience in operating at 1000 F. While Scheme D_1 shows an improvement over Scheme C_1, practical considerations favored Scheme C_1, which established the pressure at 1600 psig and temperature at 950 F.

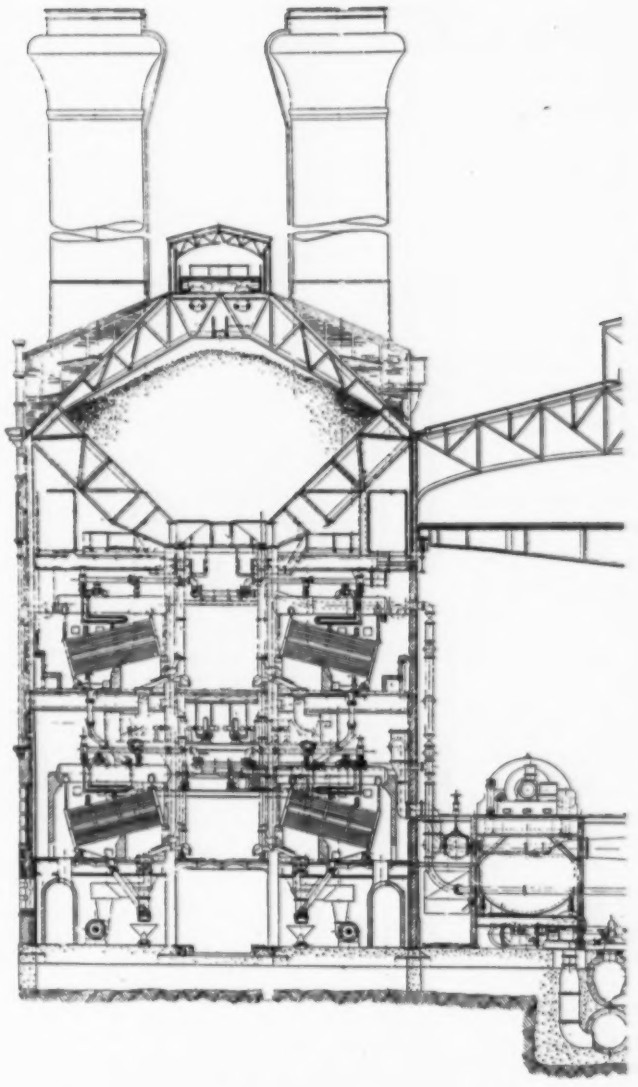

Fig. 2—Cross-section of Waterside No. 1 before modernization

Scheme	B_1	C_1	D_1	F_2
Steam at h-p turbine throttle				
Pressure, psig	1,250	1,600	1,600	2,400
Temperature, F	925	950	1,000	950
H-p flow, lb per hr	950,000	947,000	920,000	960,000
L-p flow, lb per hr	810,000	806,000	785,000	766,000
L-p temperature, F	527	494	523	500
Feedwater temperature, F	441	441	441	489
Reheat pressure, psig	...	...	...	1,535
Reheat temperature, F	...	...	...	950
H-p generation, MW	45.4	51.2	52.1	60.1
L-p generation, MW	69.1	66.8	67.3	63.9
Net h-p and l-p generation, MW	103.3	106.3	107.9	111.0
Heat rate for h-p and l-p, Btu per kwhr	10,850	10,530	10,375	10,085

All studies were made with a constant heat input of $11,200 \times 10^6$ Btu and 87½ per cent boiler efficiency.

The steam generating units selected are of the three-drum bent-tube type and were designed and furnished by Combustion Engineering Company. They are rated to deliver continuously 1,000,000 lb of steam an hour for 24 hr, at 1600 psig and 950 F at the turbine throttle valve when fed with water at 437 F. Design pressure is 1800 psig. A cross-section is shown in Fig. 4.

The boilers are arranged opposite hand to each other so that the superheater outlet of the boiler is nearest its turbine. Following past practice, a single boiler serves a

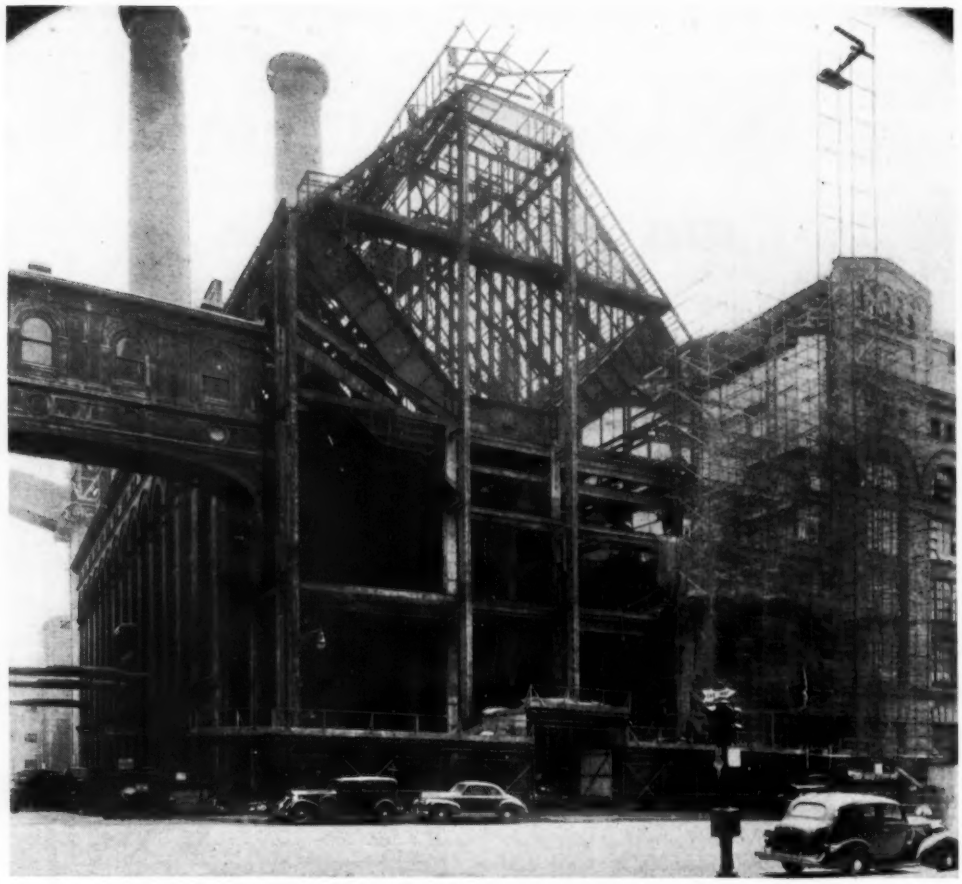

Fig. 3—Demolition progress on west wall of boiler house

single turbine, so that a nonreturn valve is not required between the boiler and the turbine, and the Boiler Code requirements cover the main steam piping to the turbine throttle. The topping turbines exhaust to the station 200-psig steam mains.

Each steam generating unit comprises a completely water-cooled, continuously slagging bottom furnace, Elesco superheater, C-E economizer and two Ljungstrom air preheaters The furnace volume is 68,500 cu ft, with a heat release of 15,700 Btu per cu ft at 925,000 lb evaporation. The lower 20 ft of the furnace-wall tubes are aluminized to prevent sulfide attack. All tubes are 3 in. diameter, with front and rear walls composed of bifurcated tubes on 3 $^1/_8$-in. centers. Side-wall tubes are on $3^1/_8$-in. centers but not bifurcated. At the superheater screen the rear wall tubes are spread four rows deep in the direction of gas travel on $12^1/_2$-in. centers.

To supply water to the furnace wall tubes, seven 10-in. OD downcomers lead from the 36-in. water drum to an inlet header located below the furnace floor. Supply tubes connect the inlet header and the individual wall headers.

The upper water drum is 60 in. ID, $3^{29}/_{32}$ in. thick and 44 ft 8 in. straight length. It is equipped with a bubble-type steam washer. The upper steam drum is 54 in. ID $4^1/_2$ in. thick and 44 ft 8 in. straight length. The lower drum is 36 in. ID, $2^1/_4$ in. thick and 41 ft straight length. A 42-in. dry drum, to increase steam purity, is interposed between the 60-in. drum and the primary superheater inlet.

The Elesco superheater is of the vertically pendant type having 29,720 sq ft of surface disposed in a primary (low-temperature) section and a secondary (high-temperature) section. It is located between the screen formed by the rear wall tubes and the downcomer bank and consists of $2^1/_8$-in. OD tubes. In the secondary section, directly behind the screen, the tubes are spaced $6^1/_4$ in. apart on 4-in. centers in the direction of gas flow. In the primary section, tubes are $3^1/_8$ in. apart on $3^1/_{16}$-in. centers in the direction of gas flow.

Tubing in the superheater elements nearest the furnace is chrome-molybdenum alloy, seamless, low-carbon, hot-finished steel. In the primary superheater nearest the furnace, it is carbon-molybdenum, seamless, low-carbon, hot-finished steel and in that part farthest from the furnace it is low-carbon, hot-finished steel.

The superheater is designed to raise the temperature of the steam to 950 F plus or minus 10 deg when delivering steam of 1600 psig to the turbine throttle. Steam temperature control at full load temperature is operative above 750,000 lb per hr.

A horizontal tube, split-type C-E economizer is provided, having 2-in. OD finned tubes 46 wide and 16 high for each half, on 5-in. vertical and 3-in. horizontal spacing. The tubes are hot-finished, low-carbon, seamless steel, with a total heating surface of 32,750 sq ft. Gas flow is vertically up with parallel water flow. The entire enconomizer is hung on the vertical water downcomer tubes, eliminating all hanger rods exposed to heat of the flue gas.

Each boiler has two Ljungstrom air preheaters, each having 130,000 sq ft of surface. The elements are 72 in. deep, disposed in layers of 32, 30 and 10 in. The upper 10 in. is in basketed sections, with a spare set of basketed elements. When this surface is fouled, it is replaced by the spare baskets, in order to reduce outage. Spare baskets are washed and stored. A single-nozzle reciprocating soot blower is located above each air heater on the air side to maintain cleanliness. A damper-controlled bypass is provided around the heaters to aid in maintaining higher plate temperatures at low loads in order to diminish fouling and corrosion.

Each steam generating unit has its own separate soot blower system, independent of that on the other unit except for common cooling water pumps for telescopic soot blowers. Two pumps, one a spare, are provided, each capable of supplying the demands of both boilers. They are automatically controlled to start and stop as required to supply water when the water-cooled telescopics are operating.

The system for each boiler consists of a control panel providing for automatic sequential or remote manual operation. It is interlocked so that only one blower at a time will operate and to prevent a telescopic unit from starting without adequate steam and water pressure. The individual blowers are controlled pneumatically; and the sequence operation is in direction of boiler gas flow, starting with furnace deslaggers, through the superheater, economizer and lastly the single nozzle mass blowers at the air preheaters.

This control system is of Vulcan Soot Blower Corporation design and manufacture, as well as all wall deslaggers and rotary units. All telescopic units are Diamond Power Specialty manufacture, modified to operate with Vulcan control.

Four C-E Raymond bowl mills serve each boiler. The individual capacity of each mill is 26,500 lb per hr when grinding 55 Hardgrove scale coal, with a maximum of 8 per cent moisture, and pulverizing to a fineness of 70 per cent through a 200-mesh sieve. The exhauster is integral with the mill and equipped with whizzer blades to lessen the wear on the exhauster blades. Star feeders driven by a Sterling "Speed Trol" control the coal flow to the mills.

The furnace is tangentially fired, with eight Type T burners per corner, disposed in two banks of four each. Each pulverizing mill serves the same two burners in each corner, and all burners are so arranged that in combination with the bypass damper, located between the boiler and the economizer, they control steam temperature.

To accomplish this, all burners and their auxiliary air nozzles are made adjustable in the vertical plane, plus or minus 30 deg. The top and upper center burners, and their air nozzles in diametrically opposed corners are tilted together by motor operation, while the lower center and bottom burners with their air nozzles, have manual tilt control, operated from each corner. The lower burners are set to maintain maximum turbulence to minimize sulfiding and maintain bottom temperature so that slag may run freely.

A change in outlet steam temperature may be effected by a change in either mass flow of the gas, or gas temperature, or both. A sensitive element in the outlet steam lead is set to maintain 950 F plus or minus 10 degrees. Any variation from this temperature causes the damper to either open or close, changing the mass flow of gas across the superheater. Thus an increase in steam temperature causes the damper to open and bypass part of the gas directly to the economizer without passing over part of the superheater surface. Conversely, closing of the damper causes more gas to flow across the superheater to raise steam temperature.

A change in steam temperature also causes the upper burners automatically to tilt either upward to increase steam temperature or downward to reduce temperature. The effect of the tilt is to cause the zone of active combustion in the furnace to raise or lower, decreasing or increasing the effective heat-absorbing surface in the furnace, to increase or decrease the temperature of the gas entering the superheater.

In the operation, it is expected that the damper will operate through a predetermined angle, after which the burners will adjust themselves to the new gas temperature requirements. Alternate movement is such that the damper position serves to bring the burner tilt mechanism

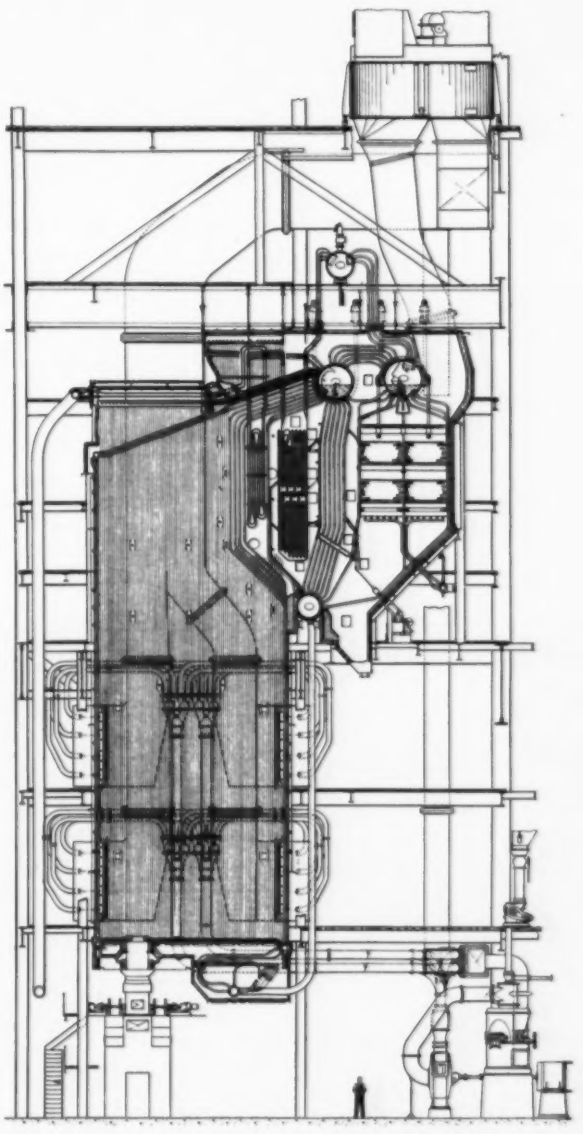

Fig. 4—Cross-section of high-pressure steam-generating unit

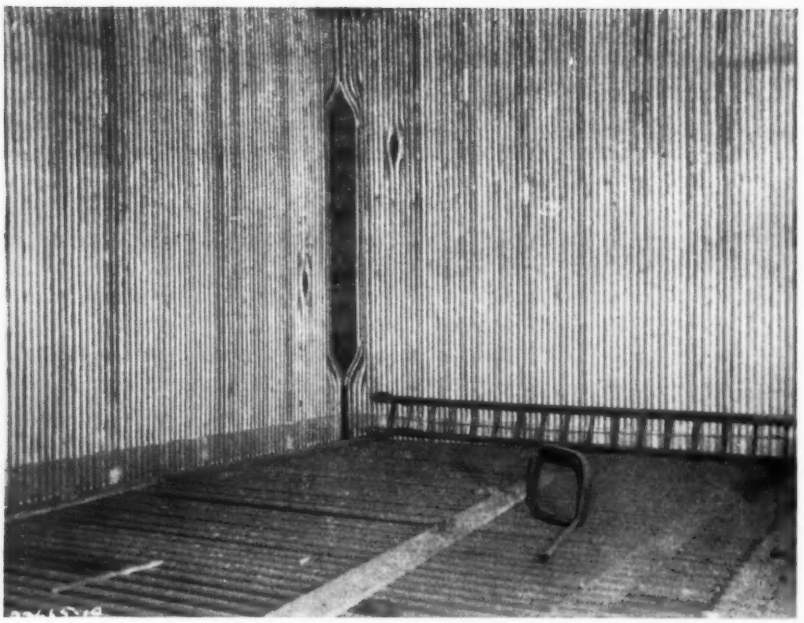

Fig. 5—Inside boiler No. 80 showing floor and aluminized wall tubes and lower burner box

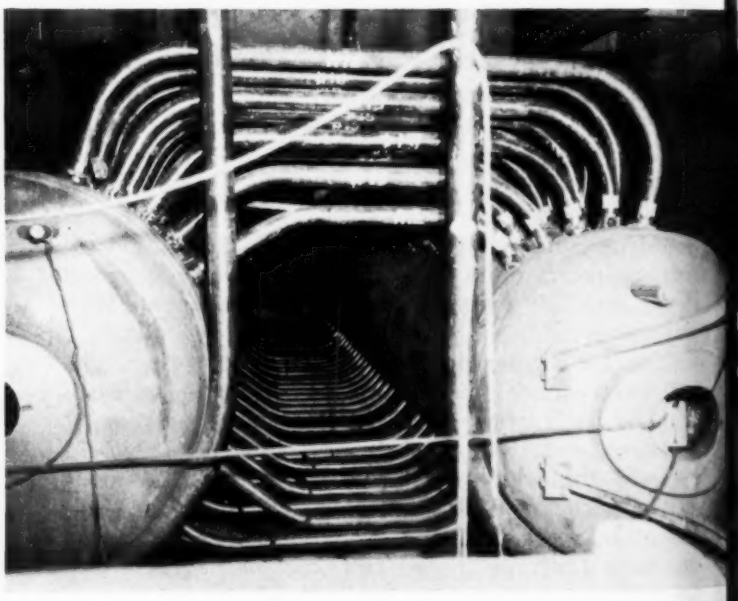

Fig. 6—No. 90 boiler drums, drum hangers and cross-over tubes

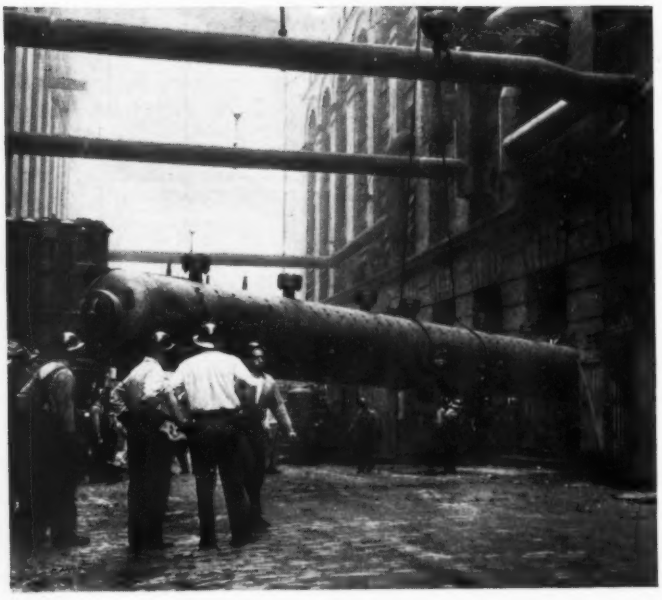

Fig. 7—42-in. drum for No. 80 boiler being moved into station; steam ties from Waterside No. 2 overhead

...views at the ...No. 1 Station

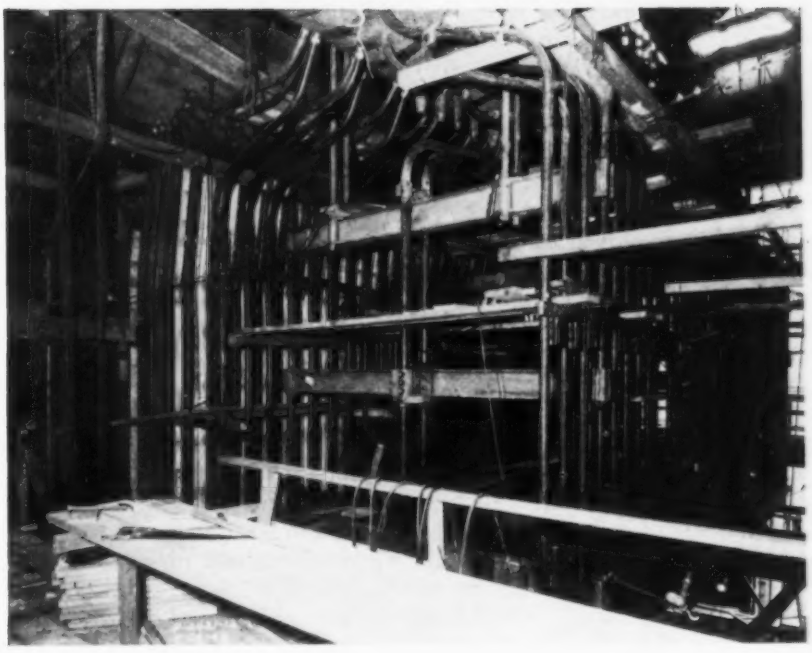

Fig. 8—Downcomer tubes showing economizer hangers

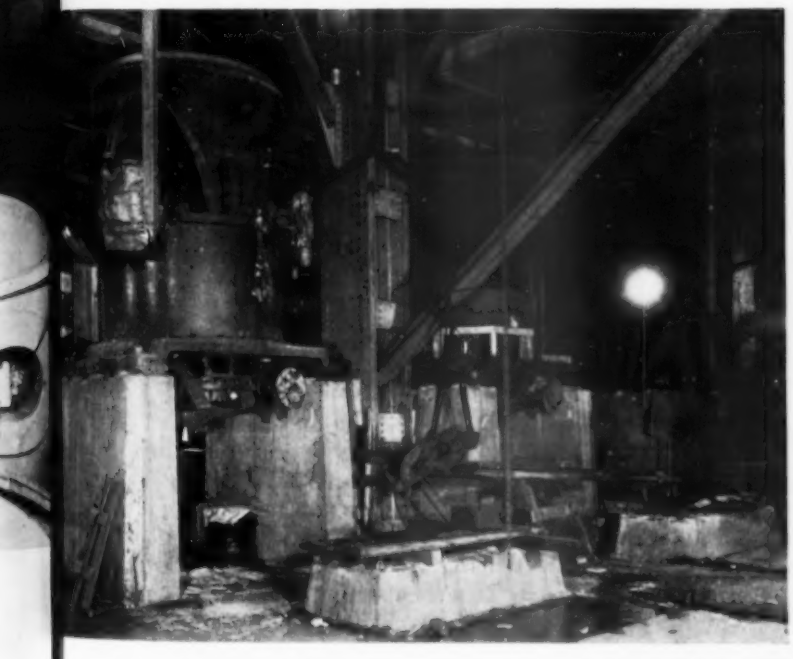

Fig. 9—Foundations for No. 80 pulverizing mills in basement

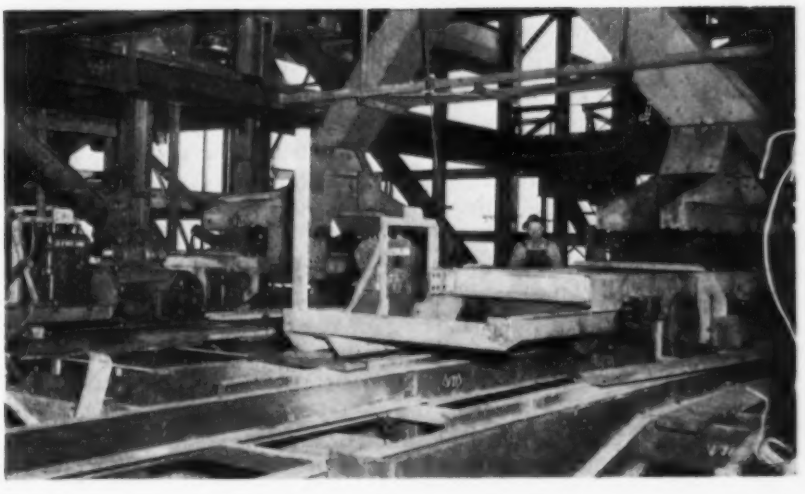

Fig. 10—Reciprocating conveyors for boiler No. 80 (right) and boiler No. 90 (left)

back into its operating range. The damper operation thus increases the overall range of superheat control.

The flame from diametrically opposed corners will travel equal distances, but different from the other two corners. Therefore, in order to have the flame meet at the same elevation in the furnace, diametrically opposed burners are separately set in angular tilt.

In addition, a secondary control, based on change in air flow, is employed to anticipate temperature change, causing the damper-burner control to over-travel or under-travel. The steam temperature element then operates to become the determining factor in the damper-burner control. Manual operation of the upper burner tilt and damper movement can be accomplished remotely from the control board.

In order to maintain as great a measure of safety as possible, and at the same time provide for the complete and instantaneous control of burners from the control board, the ignition has been arranged so that in starting a cold boiler, the control board operator gives permission to start to the burner operator by means of a signal light, push-button operated. The burner operator then opens a pilot gas cock, which in turn energizes the spark plug and ignites the pilot. In addition, a circuit through both pilot and main gas cock solenoids is closed, opening the main gas cock. The operator can then manually open a gas valve in series with the main cock and obtain ignition on the torch from the pilot. The closing of the solenoid circuits, however, transfers complete control to the control board operator and places instantaneous control for starting with a hot boiler, or to start or stop mills as required, with the board operator. When a boiler is shut down, the burner operator closes the pilot valve, which in turn closes the main gas cock by opening the solenoid circuit and transfers all control back to the burner operator. The main gas valve is then manually closed. There are four pilots and four ignition burners per corner, one each located between each pair of coal burners.

Coal Handling System

Coal enters the station from an existing conveyor system serving both stations. The conveyor inside Waterside No. 1 has been relocated to accommodate the new equipment, the air preheaters of No. 90 boiler having been spread far enough apart to allow the belt to occupy space in the center of the station.

The coal bunkers are located in the center between the two boilers, and are long in the north-south direction and narrow in the east-west direction. Above the bunker are two reciprocating conveyors running north and south in order to distribute coal over the long bunkers.

The main conveyor discharges to a hopper above these two reciprocating conveyors, and a bifurcated chute permits the feeding of coal to either of the two. The reciprocating conveyors are so arranged that they travel on tracks lengthwise of the bunkers and automatically trim the coal.

Coal falling on either reciprocating conveyor from the bifurcated chute is discharged over the front end of the conveyor, which is in itself moving in the direction of belt travel. When the head pulley reaches the end of the bunker, a limit switch stops the travel of the conveyor carriage, and reverses the circuit after a slight time delay. At the same time, an arm and gear segment has mechanically reversed the position of a flap gate in the loading boot, allowing coal to fall directly into the the center of the bunker for the period of time delay in order that complete trimming is accomplished. The time delay also allows the conveyor belt to continue to run until it can clear itself of coal. As the return travel of the carriage begins, the belt limit switch makes contact to reverse the direction of belt travel, and allow the belt to approach the falling coal stream and load in the direction of belt travel. Should the demand be heavy on any one section of the bunker, manual controls are provided so that the conveyor may be spotted to discharge to that section until level is restored.

Four Seco coal gates are located directly below the bunker openings. The coal downtake between gates and mill feeders is short and vertical and is made as an expanding section in order to minimize coal hang-up in the down-take.

The two forced-draft fans per boiler are American Blower Corporation Type HS double inlet, double width and operate at 1182 rpm. These fans are designed for 156,000 cfm of 120 F air at 15 in. H_2O static pressure. Each is driven by a 500-hp, 1185-rpm., 440-volt motor.

Two induced-draft fans are provided per boiler. Each is a B. F. Sturtevant double-inlet, double-width, "Turbovane," with erosion-resistant wheel. They are each designed to handle 265,000 cfm of 295-F gas at 13 in. of water static pressure when operating at 585 rpm. Each is driven by a 800-hp, 585-rpm, 440-volt motor.

Fan and fan-motor bearings have an alarm element imbedded in the bearing babbit to indicate high bearing temperatures. The alarm is sounded on an alarm panel in the control room, indicating the individual hot bearing, and after the alarm, the operator can, by using an indicator, determine the bearing temperature.

Dust Collection

Each boiler is equipped with two Research Corporation electrostatic precipitators, 3 sections long and 33 ducts wide, designed to remove 95 per cent of the entrained dust when handling 460,000 cfm of gas at 300 F. They are horizontal flow, steel-plate type and have 12 pneumatic vibrators, timer controlled to vibrate the plates in a predetermined sequence for a few seconds of each hour to remove the collected dust. The duration of vibration, the frequency and sequence are all adjustable within limits.

The dust collected in the precipitator hoppers and other points of lodgement in the boiler, flues and stack is handled pneumatically and discharged into existing ash silos on the dock. The ash machinery is located in an existing machinery room, also housing the Waterside No. 2 ash-handling machinery which was relocated to accommodate the new equipment.

Two complete sets of ash equipment were provided, each consisting of receiver, bag filter, vacuum pump, vacuum pump drive and water separator, with switching valves so that either may be used. A single ash header from the station to the dock was provided.

Like the existing Waterside No. 2 ash-handling system, the receiver and bag filter of each set are arranged to discharge through a swing gate housing having automatically controlled gates to discharge to either of two silos. Thus the high-carbon content fly ash from flues and stack is segregated from the lower carbon ash from the precipitators, and stored in separate silos.

Control of the vacuum pump motors located in the machinery room is by push button from an ash control panel. The system is arranged to operate either through manual control or automatic sequence, whereby the change from one loading point to another is controlled by change in pressure in the system. From the ash silos, the stored ash is discharged through existing rotary conditions to render it dustless.

Below the tap hole in each furnace are a pair of slag rakes to remove the slag from the slag pit. These rakes were developed by the Company and have been used successfully on other installations. They are relatively inexpensive to install, have low maintenance and high availability and require little attendance. Power consumption is very low as each rake makes only 3 or 6 strokes per minute, and is driven by a two-speed motor through a universal gear.

In the slag throat, between the tap hole and the slag pits, a leaf damper is installed to direct the flow of slag to either of the two pits. Pit bottoms are inclined 20 deg to the horizontal.

Water nozzles in the slag throat spray and disintegrate the slag with cold water. Mounted over each pit is a motor-driven slag rake, having several fixed flights of steel plate. The motion of the rake is alternately backward (upward) or forward (downward). On the forward motion, the rake is lifted above the slag and moved forward to the lowest part of the pit. As the forward motion ceases, the rake is lowered into the slag and the backward motion starts. Slag is raked up the 20-deg incline during the backward motion, after which the rake disengages and starts its forward motion, each successive motion bringing slag up the incline where, at the top, it drops over an apron into a car. The cars are then carried by an electric hoist truck to the ash hoppers on the dock.

Combustion Control

The combustion control was furnished by Hagan Corporation and is arranged to regulate air flow, furnace draft and coal feed to maintain steam pressure. The system has been designed so that the operator may select and operate on automatic, semi-automatic, remote manual or local hand control as required. It functions to control the delivery of the forced- and induced-draft fans through vane control mounted on the fan inlets.

Bailey Meter Company three-element control (water-flow, steam-flow, water level) is provided to regulate the speed of one or more of the feed-pump turbines as required by feedwater demands of the boiler. Water flow is balanced against steam flow and corrected for water level, resulting in an impulse which regulates the steam flow to the feed-water pump turbines and controls pump speed. Water level is brought visually to the control board mechanically by a Yarway level indicator. Paralleling this indicator is a Diamond "Utiliscope," bringing the image of the level to the control board through the television principle of camera and image screen. Another image screen at the pump control board allows the pump operator to also see water level. A water-level recorder is mounted on the vertical control panel.

The centralized boiler control consists of a bench-board and a vertical panel. On the bench-board are mounted the controls for mills, feeders, fans, steam temperature, feed-water and ignition signals together with the required position indicators. The central section of the bench-board comprises the operator's desk and telephone facilities, with the individual boiler controls occupying either end section. The vertical control panel is in front of the bench-board and is used for mounting of meters, gages and indicators upon which the operator relies for guidance. The central section of the panel is occupied by the high-pressure turbine-generator load indicators, with the boiler instruments located adjacent toward either end. The far ends of the board are occupied by the low-presure steam and heater instruments for each unit. The bench-board and vertical panel are constructed of 1-in. thick ply-wood panels covered both sides with light gray Formica, mounted on a structural steel framework. An alarm panel upon which is mounted temperature instruments and alarms as well as other miscellaneous panels are located in the control room and are of similar construction. All walls of the control room are covered with Formica panelling. In general, the bench-board, vertical panels and alarm panels are similar in arrangement and construction to those used on previous installations.[1]

The boiler feedwater is essentially condensate, but due to the fact that these stations supply steam to the New York Steam Corporation, from which no condensate is returned, the makeup requirements are heavy. A water-softening plant was installed in Waterside No. 2 in 1939, designed to treat the makeup requirements of that station. This system has now been expanded to a capacity of 2,400,000 lb per hr of mixed effluent to supply the needs of both stations. A 2,000,000-lb soft-water head tank is located in 39th Street between the two stations to act as a storage reservoir. It is arranged to float on the makeup line between the soft-water pumps in Waterside No. 2 and the condensers of the low-pressure turbines in Waterside No. 1.

In addition to pre-softening the water, provision has been made to treat chemically all feedwater entering the boilers as required to maintain proper boiler water conditions. For this purpose, three Milton Roy Simplex pumps are installed to deliver sodium phosphate to the boiler drums and three Lapp Insulator Simplex "Pulso-feeders" deliver sodium hydroxide to the deaerators. One phosphate and one hydroxide pump serve each boiler, with the third phosphate and hydroxide pump as a common spare.

The continuous blowdown system for these two boilers consists of a high-pressure flash tank where 33 per cent of the blowdown water is flashed to the 200-psig station system and a low-pressure flash tank which receives the drains from the high-pressure tank and flashes 17 per cent of this water to the 5-psig auxiliary exhaust system. The remaining blowdown, not flashed, is drained to waste.

The system is remotely controlled by push-button operation from the control room and is arranged so that a motor-operated valve at the inlet of the high-pressure tank will close in event of necessity. An interconnected free-discharge valve to waste maintains a small flow of water through the line to prevent water hammer. The system has a capacity of 150,000 lb per hr through a combination of orifices designed for various blowdown rates. The flash tanks were made by Babcock and Wilcox Co. and each tank is provided with a number of cyclone separators arranged to remove effectively the moisture from the flashed steam.

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[1] See COMBUSTION of March 1942 and August 1943.

This installation embodies in the design the features and developments which will make these boilers the most trouble-free, easiest to operate and highest availability units to date on the Consolidated Edison System.

PRINCIPAL BOILER PLANT EQUIPMENT IN WATERSIDE NO. 1 TOPPING UNITS

Steam Generating Units

Two *Combustion Engineering* units with continuously slagging bottom furnaces, Elesco superheaters, C-E economizers and Ljungstrom air preheaters. Steam generating capacity 925,000 lb per hr each at 1600 psig and 950 F, continuously. Peak capacity 1,000,000 lb per hr for 24 hr. Furnace and boiler heating surface 30,271 sq ft, superheater 29,720 sq ft, economizer 32,750 sq ft, air preheaters 260,000 sq ft. Thirty-two burners, 8 per corner, firing tangentially, each adjacent pair served by a *C-E Raymond* bowl mill. Each of the four mills and exhausters driven by a *G.E.* 300-hp, 440-v, 900-rpm motor. Four mill feeders motor-driven with *Sterling* "Speed Trol," having speed range of 10 to 40 rpm. Steam temperature control by damper and burner tilt through *Leeds & Northrup* control and *Hagan* temperature element.

Precipitators

One per boiler consisting of two units each, manufactured by *Research Corp.*, designed for 95 per cent removal when handling 460,000 cfm at 300 F.

Induced-Draft Fans

Two per boiler—*B. F. Sturtevant*, double-inlet, double-with, Design 3 "Turbovane" with erosion-resistant wheels; floats self cleaning, partially forward curved with radial tip; water-cooled bearings; designed to handle 265,000 cfm each of 295 F gas at 13 in. H_2O at 585 rpm.

Induced-Draft Fan Drives

Each fan driven by a single, totally enclosed, 800-hp, 440-v, 585-rpm motor. On No. 80 Boiler, three operating motors and one spare furnished by *Allis-Chalmers*. One operating motor, with silicone insulation furnished by *Westinghouse*. On No. 90 boiler, 4 motors furnished by *Allis-Chalmers*.

Forced-Draft Fans

Two per boiler—*American Blower Corp.* double-inlet, double-width, special backwardly pitched blades; water-cooled bearings. Each fan designed to handle 156,000 cfm of 120 F air at 15 in. H_2O at 1182 rpm.

Forced-Draft Fan Drives

Each fan driven by a single, totally enclosed, 500-hp, 440-v, 1185-rpm motor. On No. 80 boiler three operating motors and one spare furnished by *Allis-Chalmers*. One operating motor with silicone insulation furnished by *Westinghouse*. On No. 90 boiler, 4 motors furnished by *Allis-Chalmers*.

Fly-Ash Handling

United Conveyor Corp. pneumatic system with loading points at precipitators, flue hoppers and slack, discharging to existing silos. Vacuum produced by two *Nash* "Hytor" vacuum pumps each driven by a *Howell* 75-hp, 208-v 900 rpm motor, with V-belt drive. Remote automatic control for pump motors and motor-operated water valve from control panel in boiler room arranged for automatic sequential and manual control; transport capacity 25,000 lb per hr from the inlets most remote from the pumps through 5- and 6-in. single Durite pipe line.

Slag Handling System

Two slag rakes per boiler consisting of two inclined pits with rake mounted above each. Each rake operates at 3 or 6 rpm and is driven by a two-speed 3/1½ hp-motor operating at 900–1800 rpm through a universal speed reduction gear. Rakes discharge to detachable body cars for disposal at hoppers on dock. Motive power is 5-ton *Yale & Towne* electric trucks.

Combustion Control

Hagan Corp. arranged to regulate the induced- and forced-draft fan delivery through vane control and the coal feed through *Sterling* "Speed Trol" to maintain steam pressure on each boiler.

Safety Valves

Superheater header—one 3 in. *Ashcroft* 1525D; one *Power Control* 2400 psi, 950 F; three 4-in. *Consolidated* Type 1558 RD, 2000 psi, 1000 F.
Dry drum—seven 4-in. *Consolidated* Type 1558 RA, 2000 psi, 650 F.

Feedwater Control

Bailey Meter Co.—3-element, operating feed pump turbine, steam valves to maintain steam flow, water flow and water level for each boiler.

Level Indication

Remote by means of "Yarway" level indicator for each boiler, indicating in control room, and paralleled by *Diamond* "Utiliscope" indicating both in control room and at feed pump turbine control panel.

Control Bench-Boards and Panels

Light gray formica covered plywood mounted on structural steel frame. Panel boards, bench boards and room panels by *Schvets & Hadeler Co.* Structural steel frame by *Craftsmen Welders, Inc.*

Chemical Feed Pumps

Three *Milton Roy Co.* simplex motor-driven pumps for sodium phosphate each 32 gph at 2000 psig.
Three *Lapp Insulator* simplex "Pulsafeeder" for caustic, each 15 gph at 150 psig and each driven by ½-hp motor.

External Feedwater Treatment

Supplied by *Belco Division* of *Bogue Electric Co.* consisting of one sodium and one hydrogen softening tank, one salt and one acid regenerating tank, one degassifier, piping and controls and one *Proportioneer* "Chem-O-Feeder" for pH control of water leaving the degassifier.

Soot Blowers

Vulcan sequential system on each boiler consisting of 26 furnace wall blowers, 10 rotary boiler blowers, 16 rotary economizer blowers, and incorporating in the control 6 water-cooled *Diamond* telescopic blowers for screen (furnace side), 2 steam-cooled *Diamond* telescopics for screen and superheater and a single mass blower of *Air Preheater Co.* design in each air preheater.

Facts and Figures

Stokers require less furnace volume than pulverized coal for the same fuel burning rate.

•

Total operating revenues of the larger privately owned electric utilities in the United States exceeded four billion dollars for the year 1948.

•

Diamond floor plate has been found very resistant to erosion by ash and cinders when employed in fans and exhausters.

•

The specific thermal conductivity of metals is high and extremely sensitive to the presence of small amounts of impurities.

•

The specific heats of actual gases at constant pressure and constant volume vary considerably with temperature and slightly with pressure.

•

The high temperature required for the operation of the operation of the open-hearth steel making process cannot be attained without heat regeneration.

•

A new coal-mining machine has been developed which is expected to turn out from 500 to 1000 tons per day with a crew of four men.

•

The electric utilities accounted for approximately 18 per cent of the bituminous coal mined in the United States last year.

•

Time required to bring up a boiler from cold condition to full pressure and temperature is governed largely by the necessity for uniform heating, particularly of the drums.

•

The first hydrogen-cooled turbine-generator to be built in England is a 60,000-kw, 3000-rpm machine which will shortly go into service at the Littlebrook "B" power station of the British Electricity Authority.

•

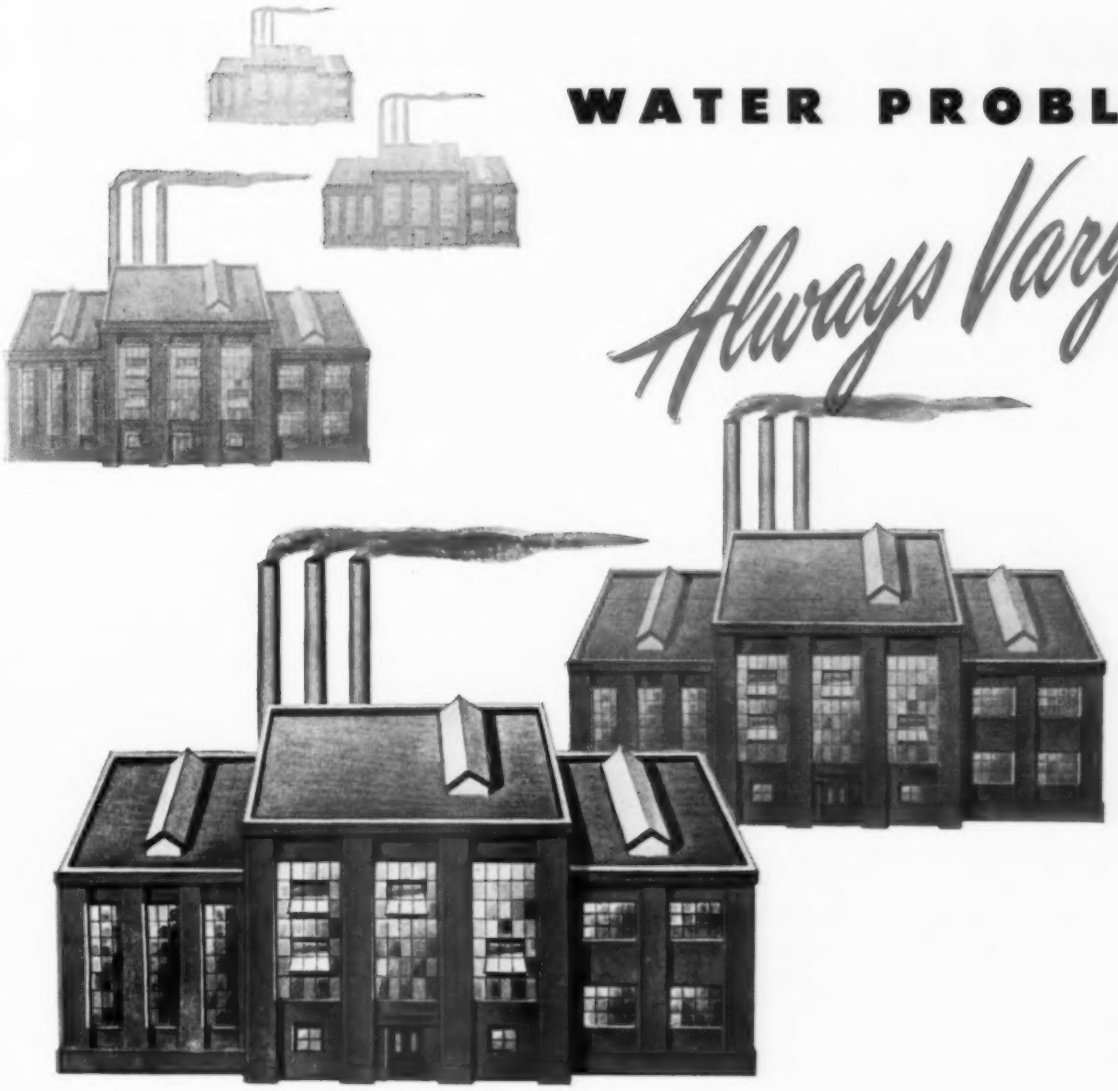
While chromium alloys are resistant to corrosion-erosion attack, chromium plating of carbon steel has not been found satisfactory for this purpose in power plant application.

•

Despite competition from oil and pulverized coal more stokers were sold for power boilers last year than for several years past.

WATER PROBLEMS

Always Vary



Water is the most common and widely used raw material. Its use can . . . and usually does . . . pose an infinite variety of problems. These problems are never identical. Variables will include the water itself, the plant equipment, the operating conditions and many other factors. The proper approach to the solution of a water treatment problem . . . whatever its nature . . . is to engage the service of specialists who provide an adequate and well-balanced program of scientific control.

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BOILER WATER CONDITIONING • COOLING WATER CONDITIONING • INDUSTRIAL WASTE TREATMENT

PERKINS ON HIGH-PRESSURE STEAM

By C. G. R. HUMPHREYS

Research Department, Combustion Engineering-Superheater, Inc.

A review of the work of Jacob Perkins and his son, A. M. Perkins, in the field of high-pressure steam generation about 125 years ago. Developments by these American inventors were carried on in England. Their thinking is shown to have been far in advance of their time, and embodied certain things that are to be found in present-day practice.

JACOB Perkins was born at Newburyport, Mass., July 9, 1766. He was of old Colonial stock that first came from England in 1631. Family adversities denied him any formal education, but he grew with great fertility of invention, and at fifteen years he is recorded as having been a goldsmith and coppersmith, succeeding to and continuing the business of his deceased master.

In 1787 he designed and made dies for copper cents produced at the Massachusetts Mint, but his task was hardly remunerative before the newly formed United States forbade state coinage, and we find little more about Perkins until 1805 when he patented a device (1)[1] for engraving banknotes "essentially founded upon the assumption that the banknote may be made to contain so great a quantity and variety of work, extremely difficult of imitation, that a single note so made would cost the counterfeiter more than he could obtain by passing several hundred of them." The intricate, but comparatively cheap paper money produced by his machines gained him appreciative notices here and abroad. There were also occasional small references to Perkins steam equipment in the United States, but these were without any elaborations.

Finding a congenial partner in Gideon Fairman, they went together to England for the purpose of seeking work and to exploit the note-engraving machine there. Particularly they sought contracts from the Bank of England, but in this quest were unsuccessful.

It was English inventors, such as Applegarth and Cowper, who opposed "the ideas of men who were foreigners, and had lately been enemies of Britain." It is interesting to note that the Peace Declaration between the United States and Britain had been ratified in 1814, while the time to which we refer was 1818.

In 1819 John Oldham used the Perkins method to produce paper notes for the Bank of Ireland and the Bank of England but failed to accord recognition to the inventor. Nevertheless, private banks sustained Perkins in his method and he was therefore enabled to work to considerable advantage. That year he and Fairman joined with an English engraver, Heath, to establish a substantial partnership with works in London.

We have thus briefly mentioned the life of an American who, at 52, emigrated to another land of promise. He found there a considerable measure of success, and also time to indulge his fancies in the pursuit of high-pressure steam in theory and application. Perkins, of course, was aware that James Watt and his predecessors had used steam at $2^1/_2$ to 7 psi; and he probably was aware of his fellow Americans, Evans and Stevens, also of England's Trevithick, who worked with steam pressures of 50 to 75 psi, and he voiced his realization of a few ideas about steam which were expressed (2) as follows:

"It is a well-known fact that water does not boil under atmospheric pressure until it has been heated to 212 F, after which all the heat that can be applied cannot increase the temperature of the steam or water. Now, add an artificial atmosphere by loading the escape valve (the surface of which is equal to a square inch) with 14 lb and it will receive 250 deg of heat with a very little

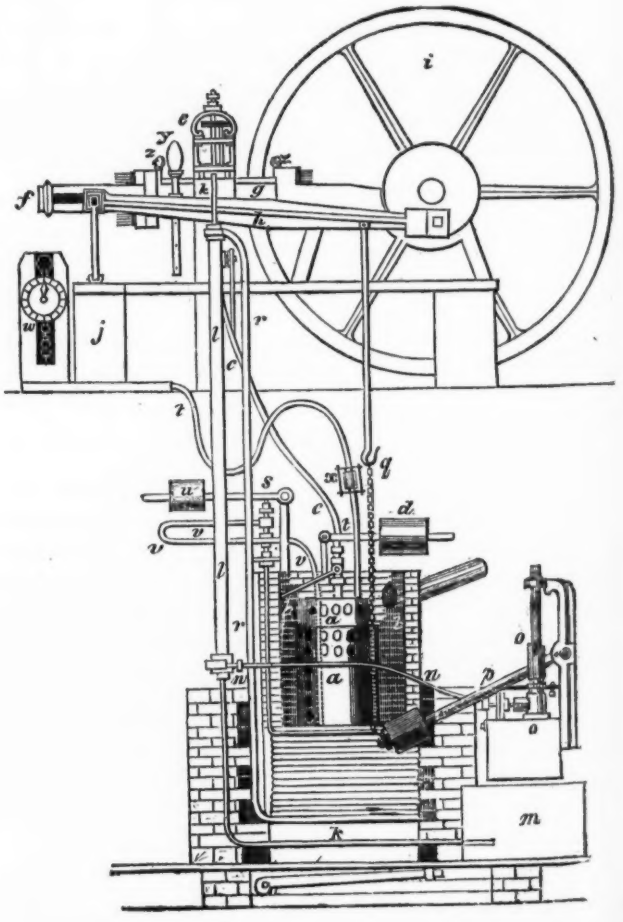

Fig. 1—Jacob Perkins' high-pressure copper boiler and steam engine, 1822

[1] Numbers in parenthesis refer to Bibliography at the end of this article.

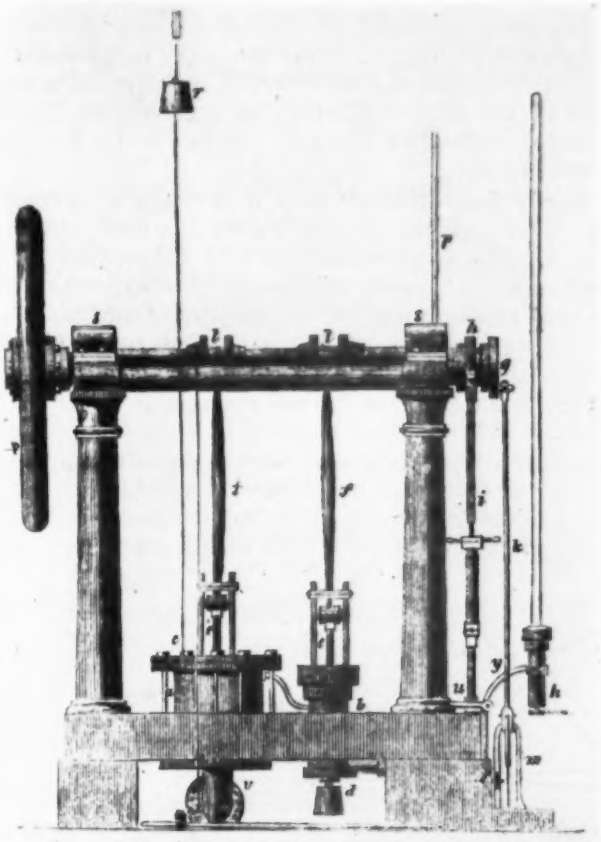

Fig. 2—Jacob Perkins' patent expansion engine

addition of fuel, and the pressure on the square inch will be doubled, or 28 lb; the mechanical action will not be double, yet it will be increased much more than the consumption of fuel. Let the valve be loaded with two additional atmospheres or 42 lb and the temperature willl be raised to 280, and will again produce double pressure, or 56 lb on the inch, and so on. If the generator be made strong enough, as I have no doubt it may be, to withstand 60,000 lb load on the escape valve, the water would not boil, although it would exert an expansive force equal to 56,000 lb on the inch, and be at about 1170 deg of heat, or cherry-red. Water thus heated would, if it were allowed, expand itself into atmospheric steam, without receiving any additional heat from what surrounded it. It is not, however, necessary to heat the water to more than 500 deg to have it flash into steam, if the generator be properly constructed."

All of this is not quite correct as we now know, but Perkins at least had sound ideas far ahead of his time, and in 1822 began a series of experiments with steam at pressures up to 1400 psi. Although not completely successful, these experiments indicated paths to successful applications at some future time.

Fig. 1, reproduced from a sketch in Elijah Galloway's "History of the Steam Engine," London, 1828, shows one of Perkins' earliest designs. It had a copper circular boiler, with 3-in. wall, surrounded by a brick furnace. The boiler was completely filled with water which was heated and prevented from escaping by a lever valve carrying the weight *d*. When the pump *o* was worked so as to force more water into the lower part of the boiler against the prevailing pressure, highly heated water was forced past the valve and into the pipe *cc*. Upon entering the engine cylinder *g*, this water flashed into steam and actuated piston *f*. Near the end of its stroke the piston uncovered a port and steam passed through pipe *kk*, which extended through the condenser *ll* and entered reservoir *m* from which the water was pumped back into the boiler. The condenser was a 4-in. copper tube about 20 ft long and supplied with cold water through pipe *nn*.

It is recorded that working pressures of from 800 to 1400 psi were attained, but that the economy of such high pressures was not established. The difficulty was not with generation of steam, but with the high temperatures to which the cylinder and other working parts of the engine were subjected, it being impossible to lubricate them with oil or tallow. To get around such difficulty, Perkins took out a patent for a metallic piston of a *peculiar alloy* that he claimed would require no lubrication.

Another example of Perkins' genius was his Patent Expansion Engine of 1827. As shown in Fig. 2, this was akin to the "uniflow" engine, and is described (3) as follows:

"The present improvement consists in a most ingenious arrangement of two working cylinders, to what may be termed a single stroke engine; these cylinders are of equal length, but the internal area of one is about eight times that of the other. The steam, at a pressure of about 100 atmospheres (1400 lb to the inch), is admitted at the bottom of the smallest cylinder, and is cut off at about one-eighth of its stroke. Having forced up its piston, the steam then rushes through a short bent tube, into the upper part of the larger cylinder; here it expands again, and forcing down the large piston, escapes near the bottom through lateral openings into the condenser, and from thence into the atmosphere. The steam that remains in the condenser at atmospheric pressure is condensed by a jet of cold water, so as to produce a vacuum therein. Both pistons act nearly at the same time, by their rods being connected to a crank above them."

The boiler serving the "uniflow" engines is shown in Fig. 3. It consisted of rows of cast-iron bars with cored holes bored to $1^1/_2$ in. diameter. These were connected

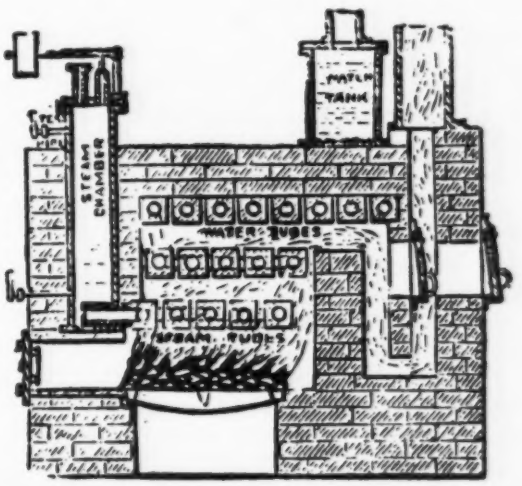

Fig. 3—Jacob Perkins' injection-tube boiler, 1827

so as to form, in effect, one continuous tube. The lowest bank was maintained by the furnace at 1000 F, and at each stroke of the engine, water from the upper bank was discharged to the lowest bank where it flashed to steam before entering the engine. Perkins commented about this boiler as follows:

"I have found by experience that to generate steam by heating water in tubes, all the parts of which are exposed to the fire, steam will become more or less surcharged with caloric, and will often show a much higher temperature for the power it is exerting than would be the case if it had had its proper proportion of water, thereby wasting much of the caloric as it passes off with the steam without a proportional power being derived, at the same time injuring parts of the engine by overheating them. To effect this important object, of ensuring to the steam its due proportion of water, I have caused a strong steam chamber to be fixed in some nonconducting material, having no part of it in contact with the fire. In this vessel I keep constantly more or less water. I also insert in the bottom of the steam chamber a steam tube, which is connected immediately with the last generating tube; this steam tube enters through one side, and at the bottom of the steam chamber it runs horizontally till it comes in contact, or nearly so, with the other side. The underside of that part of the tube which is inside the steam chamber is perforated with a sufficient number of holes to allow the surcharged steam to rush downwards and impinge on the bottom of the steam chamber; after which it rises by its own lightness through the water, taking in its ascension its due proportion of water necessary to form perfect steam, or steam of its proper density, with respect to its temperature. To ensure a sufficient supply of water to the steam chamber a small tube is connected with the pipe of the feed pump, which is attached to the bottom of the steam chamber or the steam pipe leading to it." (4)

In 1826 Perkins lectured before the Royal Society "On the Progressive Compression of Water by High Degrees of Force." (5) He had reduced the volume of this "incompressible fluid" by $^1/_{11.5}$ of its volume under a pressure of 28,000 psi. This and other lectures and his inventive traits make one discredit the reported meagerness of his education. For his achievements he was awarded both silver and gold medals by the Society of Arts in London.

One of Jacob Perkins' most noteworthy achievements was his ice machine (British Patent No. 6662) shown in Fig. 4. This was produced in 1834 and is described by Perkins as the "apparatus or means whereby I am enabled to use volatile fluids for the purpose of producing the cooling or freezing of fluids, and yet, at the same time, constantly condensing such which held the water to be frozen, while in the jacket was the volatile liquid and its vapour The pan was enclosed in a wooden box, containing powdered charcoal as a nonconductor. From the top of the jacket a pipe was led away to the suction valve of an air-pump, fixed in the middle of the wooden base. From the delivery valve of this pump a pipe proceeded to the top of a worm, contained in a worm-tub supported on the wooden base, at the end opposite to that where the jacketed pan was. The worm-tub was supplied with water, from an inlet at the bottom, and the escape was by an overflow at the top. A pipe, in continuation of the lower end of the worm, was connected to the underside of a valve box, in which was a valve loaded to about 15 lb to the inch, so that the vapour in the worm was subjected to this pressure, as well as to the cooling influence of volatile fluids, and bringing them again and again into operation, without waste." (6, 7, 8)

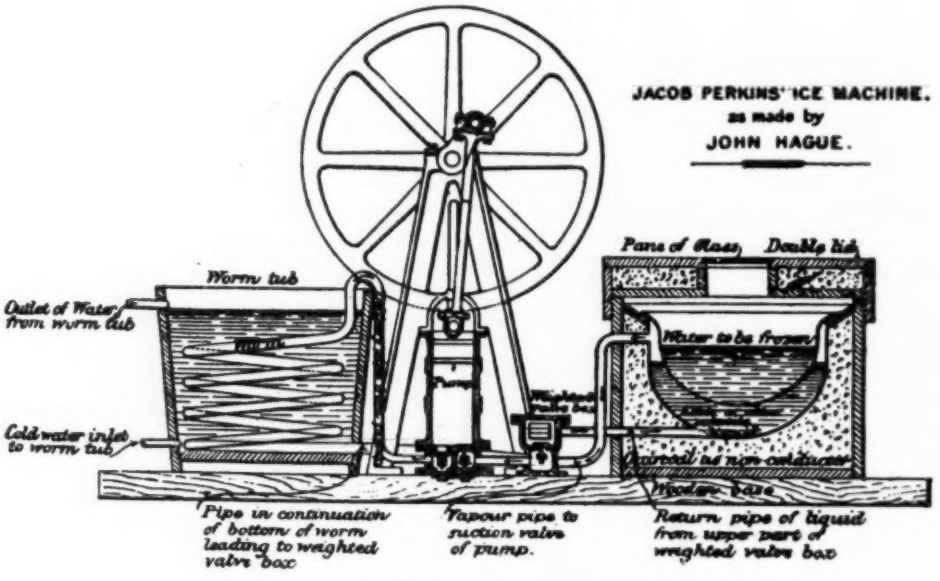
JACOB PERKINS' ICE MACHINE.
as made by
JOHN HAGUE.
Worm tub
Outlet of Water from worm tub
Cold water inlet to worm tub
Pipe in continuation of bottom of worm leading to weighted valve box
Vapour pipe to suction valve of pump.
Return pipe of liquid from upper part of weighted valve box

Fig. 4—Jacob Perkins' ice machine, 1834

The refrigeration of fluids, like water, had been considered by others in a vague sort of manner; suggestions had been made concerning ice production and water cooling by the evaporation of a more volatile liquid than water, but to Jacob Perkins would appear to belong credit for the first man-made refrigerator.

He devised numerous other schemes, but only a few of them are mentioned here. They included a method of warming and ventilating buildings (9); a steam ma-

chine gun (10); uses for superheated steam "surcharged with caloric"; a device to improve boiler circulation; and in 1840 an improved engraver which was used to make Sir Rowland Hill's first penny postage stamps, i.e., the "black pennies" that philatelists yearn to get.

Jacob Perkins retired in 1835 and died in London on July 30, 1849. His work was carried on by his sons,

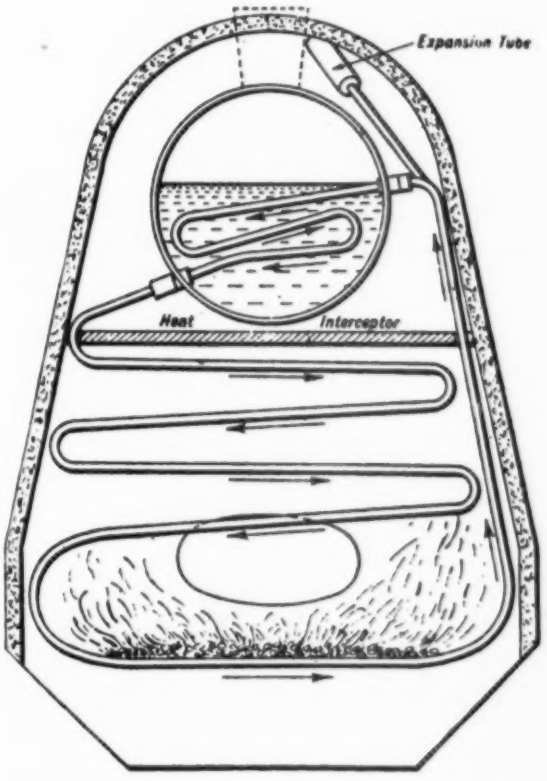

Fig. 5—Diagram of A. M. Perkins' "Hermetic" tube boiler, 1839

particularly Angier March Perkins who had educational advantages that his father had lacked.

Angier Perkins also was an American and joined his father in England in 1827, in his 28th year. In 1831, he patented the "Perkins System of Heating by Small-Bore Wrought-Iron Pipes," and applied these in the high-pressure heating of large dwellings and public buildings. These pipes were $^{7}/_{8}$ in bore × $1^{5}/_{16}$ in. diameter. Random lengths were joined up to 1000 ft, and joints were made by using right- and left-hand screw threads. The joint was formed by simply threading the pipe ends left, or right, and drawing them together with couplings. The pipes were laid to fit any form and were coiled into heaps where much heating surface was required. The temperatures in these pipes were from 120 to 550 F, but usually below 350 F.

The boilers used here were of the "ever full water" type previously devised in the United States by Jacob Perkins to prevent formations of films of bubbles against the metal subjected to very high temperatures. They were described by A. M. Perkins as follows:

"As water expands about one-twentieth of its bulk before being converted into steam, I provide about double that extra space in the 'expansion tube' which is fitted with a removable air plug to allow the escape of air when the boiler is being filled. With this space for the expansion of the heated water the boiler is completely filled, and will at all times be kept in constant contact with the metal however high the degree of heat to which such apparatus may be submitted; and at the same time there will be no danger of bursting the apparatus with the provision of the sufficient space as named for the expansion of the water.

"I find that when the circulating tubes present a surface equal to three times that of the heating coil, I have not been able to burst the tubes.

"The tubes I use are called drawn gas tubing, and the size I commonly employ is 1 in. external and $^{5}/_{8}$ in. internal diameter." (11)

The numerous applications of this system operated at pressures up to 800 psi, but equipment sizes are not mentioned. An old "Materials Received" record for 1835 contained notes on work for Perkins' boilers and heating systems in several European countries at this time.

In 1839, the previously mentioned steam machine guns were tried with success, but, for want of a war, were only used for spectacles. In this system cannon balls were expelled at great velocities from gun barrels by high-pressure steam. The introduction of rifling in barrels spelled the end of steam guns.

Under date of 1882 we read of A. M. Perkins' "indestructible engine-boiler. . .in which the boiler is removed from contact with the fire, the heat from which is conveyed to the boiler by water circulating in closed pipes; and boilers constructed in this principle have been in continuous service for 35 yr without deterioration." (12) Such a boiler is shown in Figs. 5 and 6. Natural circulation boilers of this type and patented in 1839 were reported to have been designed to operate at pressures

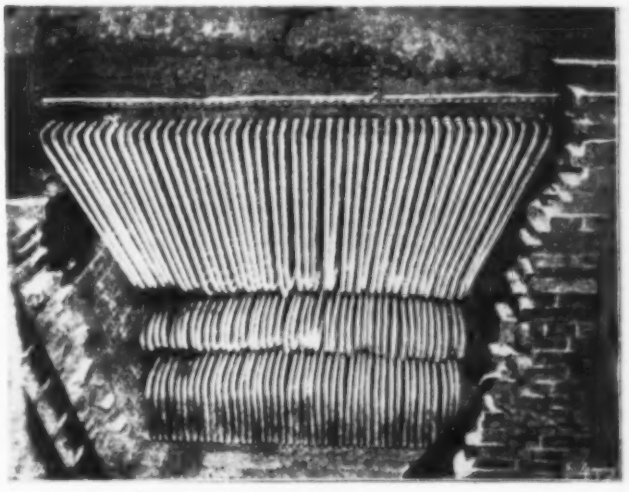

Fig. 6—A. M. Perkins' "Hermetic" tube boiler as it appeared in 1889

up to 2000 psi, although information as to capacities is lacking. Records of two such boilers cited in 1931 are as follows:

"Of two Perkins boilers still working in the Guildhall, one is said to have been in use for about eighty years, and the chief engineer states that the pipes have not lost one-sixteenth of their original diameter. The farthermost heating outlet does not necessitate a boiler pressure

of higher than 800 lb, and the pressure gage is set only for 1000 lb. In 1915 the largest of these had been in use for sixty-five years, and the other, smaller one, for forty-three years. Both were of the same general construction as shown in Fig. 5. The last one, which we always called the new boiler, had closed heating tubes about $1^1/_4$-in. external diameter and $^1/_2$-in. bore, as against 1-in. bore in the older boiler. The drum containing the free water for evaporation was about 18 ft long, egg-ended, and about 54 in. in diameter and traversed

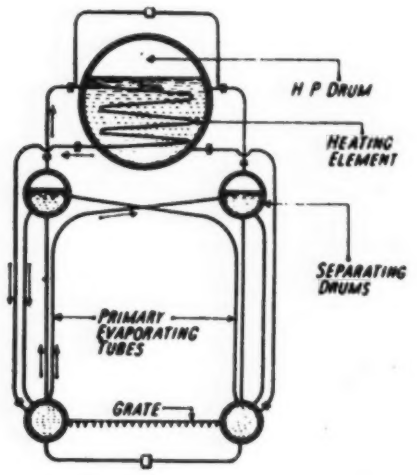

Fig. 7—Circulation diagram of Schmidt boiler which bears resemblance to early Perkins design

throughout its parallel length and below the mean water level by forty-eight closed-circuit heating pipes, or internal loops, so bent as to carry the hot water current to a lower level before leaving the boiler." (11)

Other unique devices by A. M. Perkins are not mentioned but an important resemblance is noticed between Fig. 5 and the Schmidt high-pressure boiler, Fig. 7, named for its inventor, Dr. Wilhelm Schmidt, and applied in numerous Continental boiler plants. Briefly, the Schmidt boiler has two separate water systems. One consists of a closed circuit containing distilled water which is exposed to furnace gases. The resulting steam is condensed in the high-pressure drum and repeats its cycle only as a heat-transfer agent. Like the last described Perkins system, the pressures in the primary systems exceed by several hundred pounds those in the secondary and final cycles.

In conclusion it may be pointed out that Jacob Perkins also envisaged a system akin to that of his son Angier, and Schmidt, as well as later designers such as Benson, Loeffler and others.

Angier Perkins died in England in 1882.

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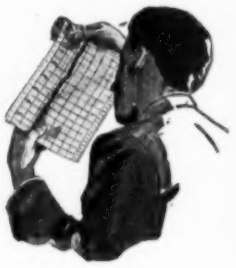

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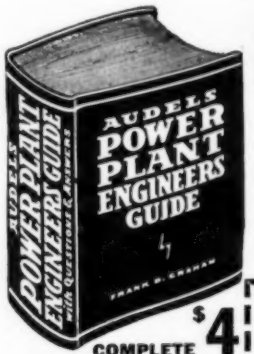

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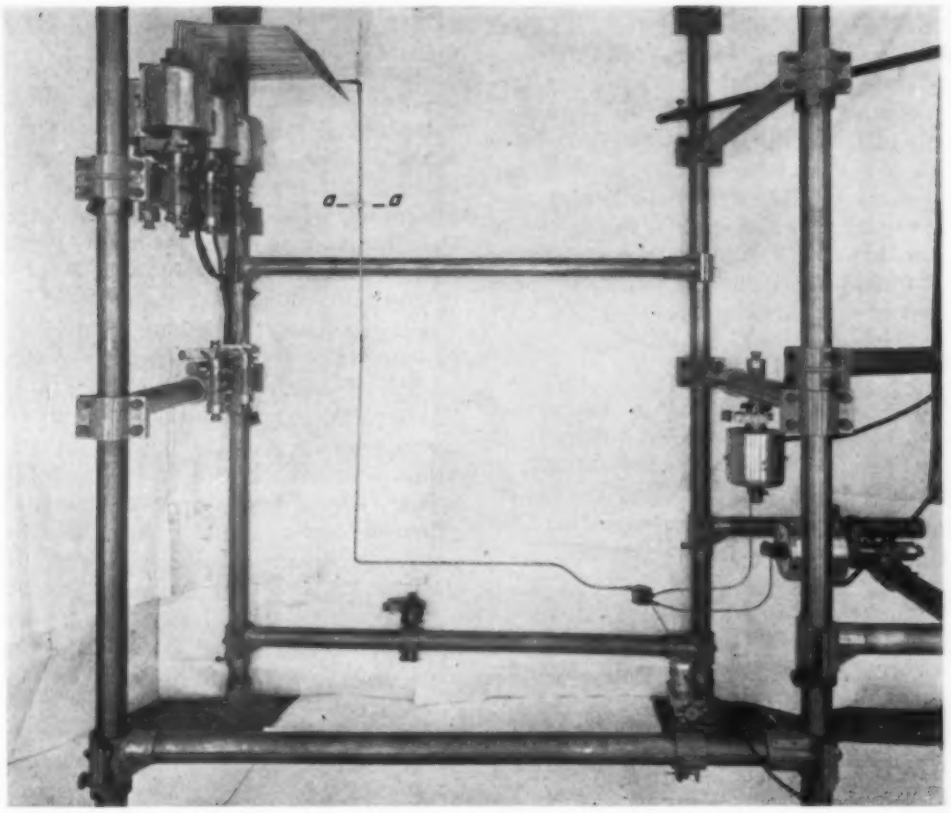


Fig. 1—Pipe model testing apparatus developed by The M. W. Kellogg Company

Model Test Analysis of Steam Piping

By LALE C. ANDREWS

Mechanical Engineer, The M. W. Kellogg Company

TO PREVENT expansion reactions from the main steam piping being transmitted to the superheater tubes, it was long common practice to restrain steam generator headers or their adjacent connections. However, with the current employment of high temperatures, this was found to involve a number of complications. Satisfactory restraints have been difficult to design; suitable structural members have seldom been available at the desired locations; and the actual effectiveness of the restraint has often been open to question.

An interesting deviation from this practice has been introduced in the design of the superheater and main steam piping for two Combustion Engineering steam generators for Dunkirk Steam Electric Station of the Buffalo Niagara Electric Corp. In this arrangement the superheater header will be suspended on spring hangers. The 124 tubes which feed the header, and which emerge from the roof of the steam generating unit approximately 18 feet to the rear, thus become structurally a part of the main steam piping. Because of the additional flexibility thereby provided, reactions at the turbine are relieved and a saving of expensive forged and bored chrome-moly piping is consequently effected in this manner.

Stresses in piping systems can be determined by model tests in which displacements proportional to thermal expansion are applied. Resulting forces and moments are measured by means of electrical strain gages and converted to full-scale values. A description of tests carried out on the main steam piping system for the new Dunkirk Steam Electric Station of the Buffalo Niagara Electric Corporation is presented.

The stress analysis of this intricate piping system, consisting of 124 branches at the superheater end and two at the turbine end, with a partial restraint at the throttle valve, was made feasible through the use of the pipe model testing apparatus developed by The M. W. Kellogg Company. For very complicated piping systems the model test method is a means of finding solutions which are difficult to obtain

by direct calculation, while for simpler systems it serves as an experimental check against theoretical results.

The model test method of analysis consists of displacing the ends of a scale model of the piping system in proportion to its calculated thermal expansion from some assumed fixed point. The model end reactions which are thus proportional to those produced in the actual pipe are measured and converted to full scale. The moments thereby derived are then transferred mathematically to critical locations throughout the system, and from these values the maximum stress in the system is obtained.

*Testing Apparatus**

The model testing apparatus consists of a tubular steel framework of rectangular shape extending from floor to ceiling of the laboratory. Movable arms are provided to support the devices for displacing the model and measuring the reactions. This equipment may be placed in any position to accommodate the configuration of the model.

Fig. 1 shows the general construction of the model testing apparatus with the model of the main steam system of the Dunkirk Station in position for testing. Attached to the ends of the model are the cylindrical measuring heads which are carried on the displacement slides fastened to the arms of the framework.

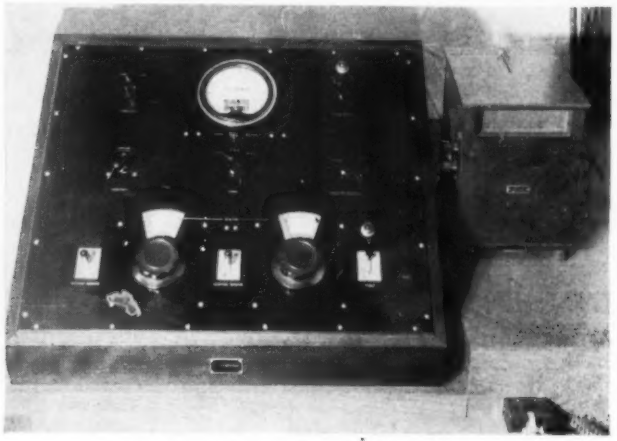


Fig. 2—Panel control board for model tests

The displacement slides are operated by micrometer screws with thimbles graduated in thousandths of an inch. Each unit consists of two slides at right angles to each other, one swiveling about the centerline of the other so that the two slides are capable of accomplishing displacements along the three coordinate axes.

The measuring head consists of a six-arm cross suspended by means of thin struts to six cantilevers. When a moment or force is applied to the end of one of the arms, a deflection of a combination of the cantilevers results. To each cantilever are attached two SR-4 electrical strain gages which form two arms of a Wheatstone bridge. In this manner the deflections of the cantilevers, and thus the loads causing the deflections, are measured electrically. Fig. 2 shows the switch panel provided for this purpose and calibrated to read in hundredths of a pound.

* For a more complete description and explanation, see two articles by the author in the August 1945 and August 1947 issues of *Heating, Piping & Air Conditioning* under the respective titles of "Analyzing Pipe Stresses by Tests of Models" and "The Model Test Method."

Application of Model Tests

In constructing the model to be tested a scale of length is selected so that the model will conveniently fit within the physical bounds of the testing apparatus. Where more than one pipe size, temperature and material are concerned, the ratio of the products of the moments of inertia by the moduli of elasticity of the various parts of the pipe line must be maintained in the model. The material usually found most satisfactory for model testing is cold rolled steel rod ranging from $^1/_8$-in. to $^1/_2$-in. by $^1/_{64}$-in. increments. Where flexibility factors of pipe elbows and bends are of serious importance in the overall results, models constructed of steel tubing are used.

After its construction the model is placed in the testing apparatus with the ends rigidly attached to the measuring heads. An initial reading is taken to establish a zero point. Then displacements proportional to thermal expansions are applied to the model by means of the displacement slides. Readings are again taken, from which the initial readings are subtracted to determine the loads on the various cantilevers due to the displacements applied. Usually three sets of readings are taken to avoid errors, and an additional check is made by summing the forces in each set of readings, errors being indicated by deviations from zero.

From the readings thus taken the component moments and forces at the ends of the model are calculated. They are then converted to the full scale of the piping system by means of the following relationships:

$$\frac{F_p}{F_m} = \frac{E_p I_p}{E_m I_m} \times \frac{\Delta_p}{\Delta_m} \times \frac{L^3_m}{L^3_p}$$

$$\frac{M_p}{M_m} = \frac{E_p I_p}{E_m I_m} \times \frac{\Delta_p}{\Delta_m} \times \frac{L^2_m}{L^2_p}$$

where F = force, M = moment, E = modulus of elasticity, I = moment of inertia, Δ = amount of expansion (or displacement) of the "free" end with reference to the fixed end, and L = length. The subscripts m and p refer to the model and the pipe, respectively.

The moments thus obtained may be transferred mathematically to critical positions on the piping system for calculation of the maximum stress.

Dunkirk Piping Tests

It will be of interest to study this system, the configuration of which is shown in Fig. 1, and its action under thermal stress as revealed by the model test methods. The solution of the problem consists of the determination of (1) the thrusts and moments exerted by the piping system upon the equipment to which it is connected, (2) the stresses created by the attendant reaction within the pipes themselves, and (3) the deflections of the various portions of the system. The last-mentioned information is desired to aid in the design of hangers to support the piping.

An important factor in power piping design is to keep the expansion forces within allowable limits to protect the turbine and steam generating unit. Also, the maximum stress in the pipe must be held within that permitted by the applicable code. Solid hangers must be placed only at points of little or no movement, while spring hangers must have adequate play to permit the pipe to deflect without excessive restraint.

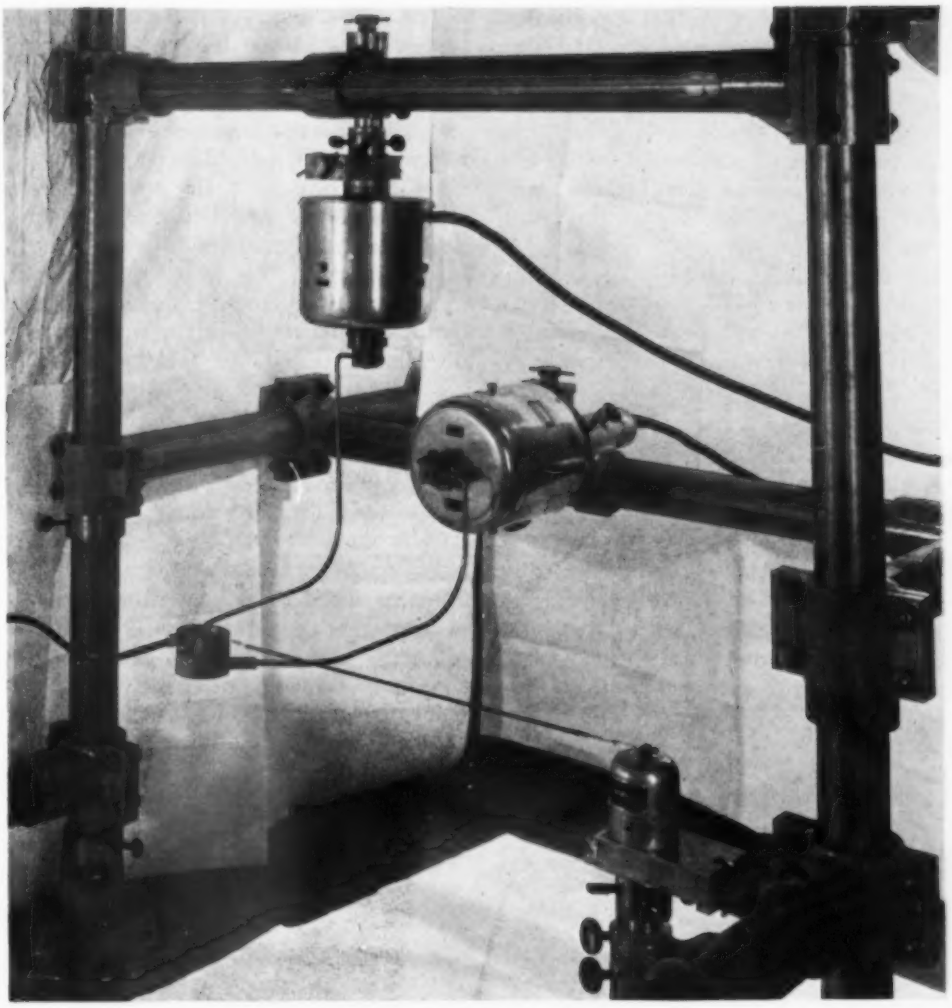


Fig. 3—Turbine end of main steam piping for Dunkirk Steam Electric Station in place for testing, showing throttle valve and divided turbine leads

Fig. 3 shows the turbine end of the model. The tie rod represents the unidirectional guide for the throttle valve. The small measuring head is simply a cantilever for the measurement of a single force. Moments and thrusts at the turbine inlet connections are obtained from measurements taken on the two large heads. It should be noted that the turbine manufacturer's piping from the throttle valve to the turbine is included in the test. This is an important part of the piping and has a definite effect upon the stresses and deflections throughout the system.

The superheater end of the model is shown in Fig. 4. In order to duplicate the structural conditions of the actual superheater tubes, it was deemed necessary to include the entire 124 tubes. However, only readings taken on the center and end banks were used in evaluating tube stresses, those in the intermediate tubes being assumed to fall within these limits. Because of the small force produced by the model of an individual tube, measurements were taken on six tubes massed together for the end banks and on eight tubes for the center bank. The intermediate tubes were massed together in two banks for the purpose of balancing the forces to zero.

In the case under consideration, the action of the superheater outlet tubes and header caused by the expansion of the piping system should be of particular interest to power engineers. It will be seen that this system consists essentially of one vertical and one horizontal run, as shown in Fig. 1. The action of the vertical downcomer is to push the superheater outlet header upward and to produce in it a counterclockwise rotation that tends to increase the angle between the sloping and horizontal portions of the tubes. This, in turn, moves the header to the right, which is in the direction of the turbine. Similarly, the expansion of the tubes pushes the header to the right.

On the other hand, the action of the horizontal run of the main steam line is to thrust the header to the left and to produce a clockwise rotation in it. This tends to decrease the angle between the sloping and horizontal portions of the tubes, causing a further movement of the header to the left, which is in the direction of the steam generating unit. Also, the bowing of the horizontal portion of the superheater outlet tubes permits an increased rotation of the sloping portion, thereby resulting in a greater movement of the header to the left.

The net result of the effects just described is to move the header toward the turbine a distance a little more than half as great as the unrestrained expansion of the tubes from their point of anchorage.

It will be recalled from theoretical mechanics that the deflection of a beam is inversely proportional to the first power of the moment of inertia but directly proportional to the cube of the length. In the case under considera-

tion, though the moment of inertia of the 124 superheater outlet tubes is less than that of the single heavy-walled main steam line from the header to the turbine throttle valve, the approximately 60-ft horizontal run of the larger pipe is deflected more than the 18-ft horizontal run of the tubes. The result of these deflections is that the lower end of the downcomer moves down about twice as much as the upper end moves up. Hence the point of zero deflection, shown at *a-a* in Fig. 1, is nearer to the upper end; and it is here that a rigid support may be placed, permitting free movement in the horizontal plane. In this manner correct distribution of the expansion in the upper and lower sections of the system is assured.

Value of Model Tests

From the foregoing observations it should be apparent that many actions take place in an intricate piping system which are not obvious from mere inspection of a drawing. Experience will, of course, improve the chances of a correct visual analysis. However, even the most skillful analysts are sometimes at a loss to explain the results of mathematical analysis until the visible contortions of a model of the piping system make the action clear.

The model test is of particular value where the piping system must be redesigned again and again until a certain desired result is attained. The model can be altered without removing it from the testing equipment, and only such readings need be taken as affect the values required. Such a problem occurs in the design for certain allowable thrusts at the turbine inlet nozzles. Until the reaction is reduced to the allowed value, the analyst has little interest in the effects in the remainder of the piping system. Yet, if the line were being calculated instead of being model tested, repeated complete mathematical solutions would be required for each trial until the allowed thrust was obtained.

Summary

The test just described is but one of three to be carried out for the main steam and reheat piping systems of the Dunkirk Steam Electric Station of the Buffalo Niagara Electric Corp. With the present trend toward the reheat cycle in large central stations, additional complications are introduced in the design of main steam piping connecting steam generating units to turbines. The method of model pipe tests developed by The M. W. Kellogg Company provides an effective tool for assured experimental solutions of these problems.

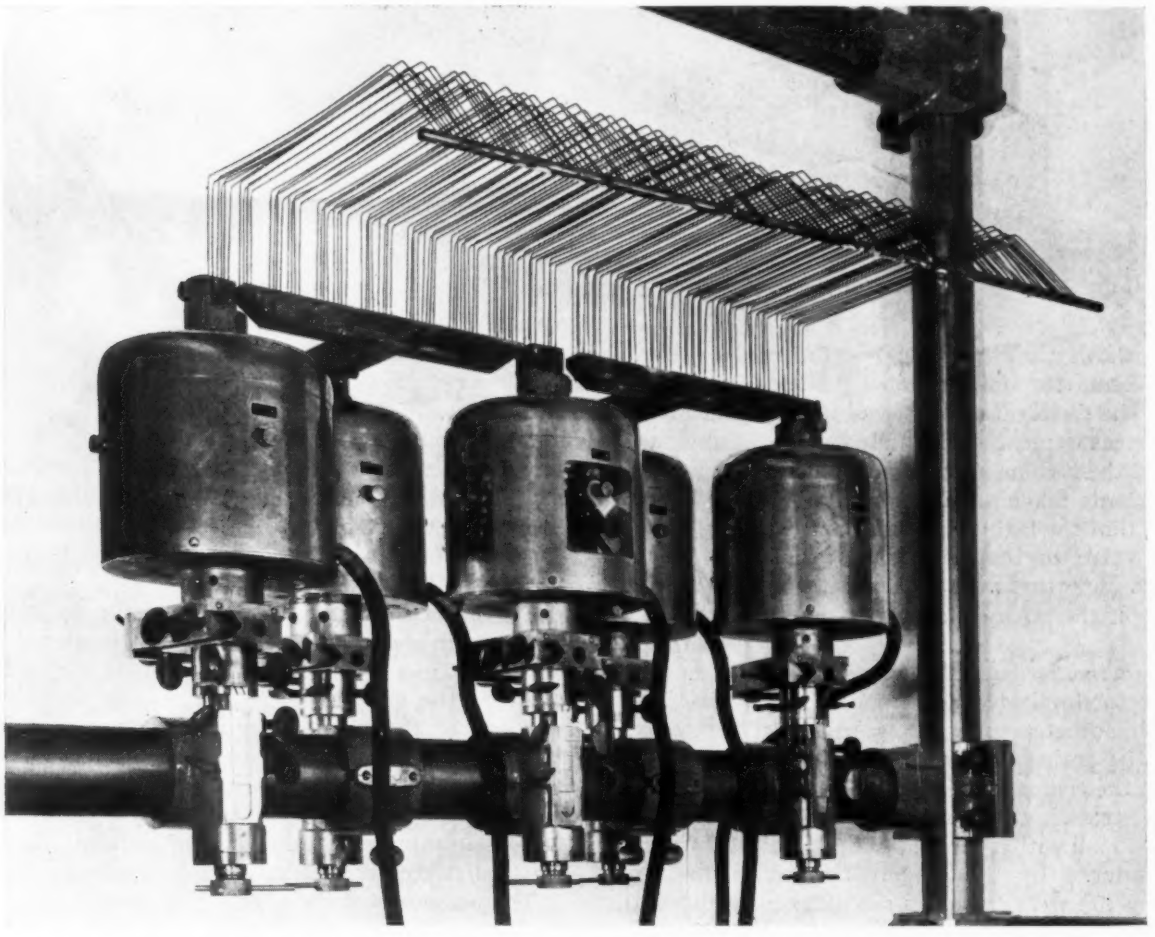
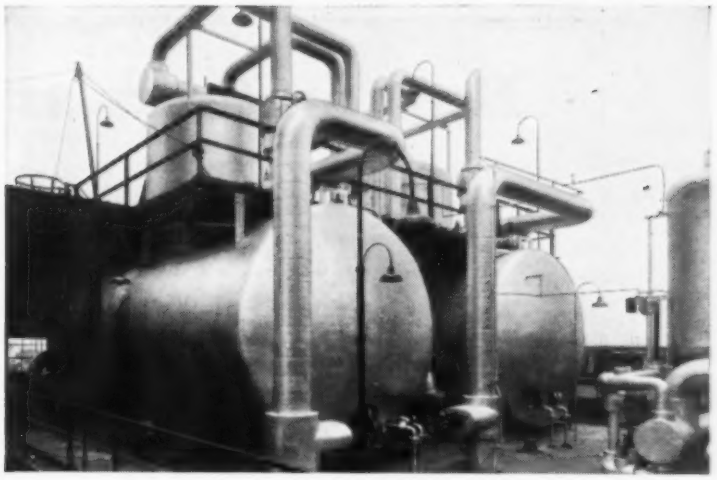


Fig. 4—Superheater end of main steam piping for Dunkirk Steam Electric Station in place for testing, showing individual superheater elements and principal downcomer



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Economizers and Air Heaters in Marine Power Plants

Excerpts from a paper by D. M. Schoenfeld* and E. P. Worthen† at the January meeting of the New England Section of The Society of Naval Architects and Marine Engineers. The authors discuss certain fundamental considerations in the application of economizers and air heaters of both the tubular and regenerative types, and particularly the steam air heater with reference to its place in the steam cycle for different operating pressures and temperatures.

THE amount of heat that must be absorbed from the products of combustion by heat-recovery equipment following the boiler is established by the desired efficiency of the steam generating unit and by the operating steam pressure. The former determines the maximum temperature at which the flue gases may be discharged to the stack, since the major losses will be the sensible heat in the dry gas and in the water vapor; and the latter sets the saturation temperature and therefore the minimum value that can be approached by the temperature of the gases leaving the boiler.

Whether the heat-recovery equipment is an economizer, an air heater, or a combination of the two, must be determined from consideration of the overall plant cycle and from a study of the inherent structural and operational characteristics of each type of heat exchanger.

Stimulated by higher costs for fuel and attendance, increasing attention has been given to the advantages to be obtained from thermodynamic cycles employing higher steam pressures and temperatures. Fullest advantage from such cycles is gained by extension of bleeding to additional stages of the turbines for feed heating, or using the surplus steam over feed-heating requirements to heat air for combustion. Utilization of additional feed heating produces feedwater temperatures in the range of 380 to 420 F.

It is apparent that with feedwater supplied in this temperature range an economizer alone cannot accomplish the reduction in gas temperature to the value required for high boiler efficiency. On the other hand, if all the heat recovery were to be attempted with only an air heater, its size or draft loss would become excessive, and the outlet temperature might reach a value that would cause operating troubles. Therefore, a combination of economizer and air heater is used, and careful consideration given to the proportion and arrangement of each type of surface. The temperature rise of the feedwater in the economizer should be limited so that the outlet water temperature is at least 50 to 100 deg F below saturation temperature in order to avoid steaming.

An important consideration in boiler design for high pressures and temperatures is the fact that the superheater outlet temperature will increase on failure to heat the feed to the design temperature. A boiler receiving feed at high temperature has inherently a greater opportunity for the superheater outlet temperature to become excessive than one having a low feed temperature. In view of this, consideration is frequently given to some form of superheat control whenever superheat temperatures are 850 F or more and feed temperatures in excess of 300 F.

In the attempt to choose between an economizer and an air heater, or to arrive at the best proportions of the two types of equipment, it becomes difficult to separate the designer's first concern with the amount of heating surface, draft loss, space requirements, cost, etc., from the operating problems.

The economizer must be designed for internal pressure somewhat higher than that of the boiler and the arrangement of water flow is made counterflow to that of the gas, in order to take advantage of the higher mean temperature difference. Water velocity should be kept high enough so that the resultant pressure drop will provide uniform distribution among the circuits. If distribution is not equalized, heat absorption is decreased by the lower mean temperature difference, and there is the possibility that steaming may occur in those tubes which have less than their share of water flow. Furthermore, the water velocity through the tubes should be high enough so that at lower rates of steaming the pressure loss will exceed the static head; otherwise recirculation is likely to take place.

The principal resistance to the transfer of heat from the flue gases to the water lies in the gas film on the outside of the tube. This condition, along with the relatively low temperature difference, as compared to some other portions of the steam generating unit, encourages the application of extended heating surface.

Ordinarily the gas makes a single cross flow pass over the economizer surface; and whatever share of the

* Manager of Development, Combustion Engineering-Superheater, Inc.
† Chief Engineer, Shipbuilding Division, Bethlehem Steel Company.

total draft loss has been allotted to this item of equipment is of advantage in increasing the controlling gas film heat-transfer coefficient, thereby reducing the required amount of surface.

Internal corrosion of economizers can be prevented by proper installation and operation of equipment to deaerate the feedwater. External corrosion may sometimes occur on the coldest tubes (at the inlet-water, gas-outlet section), if the metal temperature falls below the dewpoint of the gas. Fouling and acid corrosion are more likely in this region. However, since the temperature of the economizer metal does not get as low as that in the air heater, external corrosion is not as likely.

Air Heaters

In tubular air heaters there is considerable resistance to heat flow through the gas film on the outside of the tubes as well as through the air film on the inside. Since these resistances are usually of about the same magnitude, extended heating surface would have to be applied to both the inside and the outside of the tube. But, because of the attendant complication, this does not find application and straight plain tubes are used. These are subjected to pressures of only a few inches of water, hence can be of the thinnest wall consistent with sufficient mechanical strength.

Because of the air and gas films in the air heater compared to only a gas film in the economizer, the overall coefficient of heat transfer in the air heater is lower, and a larger amount of surface is required for a specified heat recovery.

The quality of fuel oil burned in marine boilers today has far-reaching influence on the steam generating unit design, but only its effect on the economizer and air heater will be considered here. Sulfur content has increased, and this, together with catalyst residuals from cracking processes and often lack of attention to proper combustion at low rates of operation, produces flue gas charged with acid and hydrocarbon residues and with a high dewpoint. The high efficiencies demanded of modern steam generating units require that the temperature of the flue gas leaving the unit be reduced to the range of 280 to 340 F. This is closely approaching the dewpoint and in some cases may even be below it, thus promoting deposits of acid and hydrocarbon.

If only the water vapor content of the flue gas could be considered, the matter of dewpoint with respect to the metal temperature would present no serious problem. But the situation is not so simple. A portion of the sulfur present in the fuel oil is oxidized to sulfur trioxide. This dissolves in the water vapor which is always present to form sulfuric acid, very small quantities of which in the flue gas will exert a pronounced influence in raising the effective dewpoint. The dewpoint of flue gas from bunker oil, as customarily supplied to ships today, may be considered to range from 300 to 350 F. This is substantially coincident with the temperature range to which flue gases leaving the steam generating unit must be reduced to obtain efficiencies of 87 to 88 per cent.

With a regenerative type of air heater, lower flue gas temperatures are permissible, compared with the tubular recuperative type, and higher overall efficiencies are possible. This situation arises through the nature of this air heater, since the metal in the corrugated plates is alternately heated and cooled. Thus, there is a tendency for moisture condensed on the part being cooled to evaporate when this part is subsequently heated. Fairly extensive applications of regenerative air heaters have been made in foreign marine practice with satisfactory results.

Recently, steam air heaters have been developed and used on a number of vessels. Bled steam is used to preheat the air for combustion and the amount of steam condensed in the air heater represents a saving in the heat loss to the condenser just as does the bled steam in a feedwater heater.

Since the condensing steam film coefficient is very high, extended heating surface on the air side can be used to good advantage, and the fact that both heat exchange fluids are clean is also an advantage. The tubes and extended surface can be closely spaced on the air side without risk of fouling and no provision for cleaning need be made. Corrosion is not a problem on either inside or outside regardless of metal temperature. Moreover, small diameter tubes are adequate to handle the steam flow, and compact arrangements are possible.

Usually anywhere from 10 to 45 psi is an acceptable bleed point for the steam air heater, whereas the high-pressure feed heater usually employs steam at 80 to 200 psi. The lower pressure bleed point is, of course, the more efficient and it is this fact that makes the improvement in cycle efficiency with the steam air heater comparable to that which can be obtained with an additional stage of feed heating.

Outage of any heat-exchanger, whether it be a steam air heater or high-pressure feed heater, will affect performance of the power plant cycle. Operation with the high-pressure feed heater secured will reduce the temperature of the feed to the boiler and this in turn results in less steam being produced per pound of fuel burned. The effect of power output is slight, but the effect on boiler performance is marked. Substantially the same quantity of fuel is burned, but the reduced steam flow through the superheater results in a considerable increase in superheat. On the other hand, securing a steam air heater has practically no effect on superheat and simply reduces the efficiency of the cycle.

For the 400-psi, 750-F steam cycle the gas air heater and high-pressure feed heater have proved generally satisfactory; for 600 psi, 850 F, an economizer and steam air heater combination appears to have a number of advantages; and for 900 psi, 850 to 900 F, the use of an economizer and two stages of steam air heating appears to offer advantages similar to those found with the 600-psi cycle.

It should be noted that for the range of pressures and temperatures here considered, the cycle which provides the optimum efficiency is one having both economizer and air heater. An economizer used in conjunction with a gas air heater makes it possible to obtain a low uptake temperature without an unduly large air heater. Since the problem of maintaining a clean air heater varies directly with the size of the heater, this arrangement is frequently accepted despite the fact that the low tube temperatures encountered in the air heater section may present a corrosion problem and increase the difficulty of removing soot.

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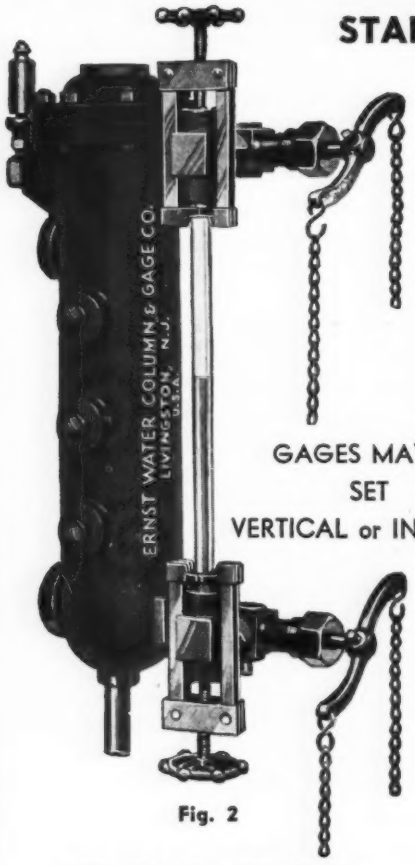
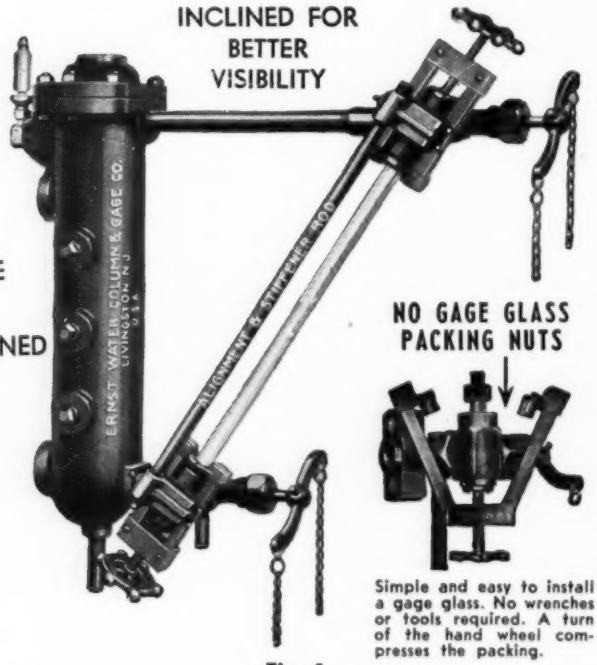
— OTHER COLUMNS TO SPECIFICATIONS —



GAGES MAY BE SET VERTICAL or INCLINED

Fig. 2

High and Low Alarm Column equipped with Split-Gland Type Adjustable Vertical Water Gage.



INCLINED FOR BETTER VISIBILITY

Fig. 1

High and Low Alarm Column equipped with Split-Gland Type Adjustable Inclined Water Gage.

NO GAGE GLASS PACKING NUTS

Simple and easy to install a gage glass. No wrenches or tools required. A turn of the hand wheel compresses the packing.

Fig. 83

No. 5 High and Low Alarm Column with Vertical Gages and DCP Weighted Type Try Cocks.

GAGE GLASSES—Tubular & Flat Type

High Pressure Composition Rubber Washers

ALL SIZES

Std. Pattern
Fig. 22

Fig. 21
Lip-Mold Pattern

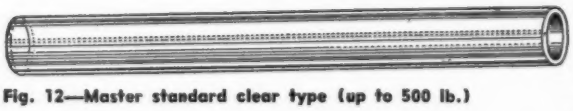


Fig. 12—Master standard clear type (up to 500 lb.)

Fig. 23X—Master clear and red line extra strong (up to 1000 lb.)

Fig. 14—Master standard red line (up to 500 lb.)

reflex type B

plain type A

Ernst Master gage glasses are noted for high resistance to pressure and temperature strains, clouding and corrosion.

Sizes—Lengths from 1 to 144 in. Outside diameters—⅜", ½", ⅝", ¾", ⅞", 1", 1⅛", 1¼" and 1½".

GAGE GLASS GUARDS and ILLUMINATORS

Fig. 31

GUARD AGAINST ACCIDENTS BY SPECIFYING ERNST PLASTIC SAFETY GUARDS

NON-BREAKABLE

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Fig. 10

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Dedication of Coal-to-Oil Plants

The Bureau of Mines will dedicate two new coal-to-oil demonstration plants on the anniversary of VE-Day, May 8, at Louisiana, Mo., less than 100 miles above St. Louis on the Mississippi River.

First of their kind in this country, these new plants will employ different processes to convert coal and lignite into the high-quality synthetic liquid fuels that ultimately should free us from dependence on foreign sources of oil. They are being erected at a combined cost of $15,000,000 to serve as a proving ground for American coals, equipment and processing methods.

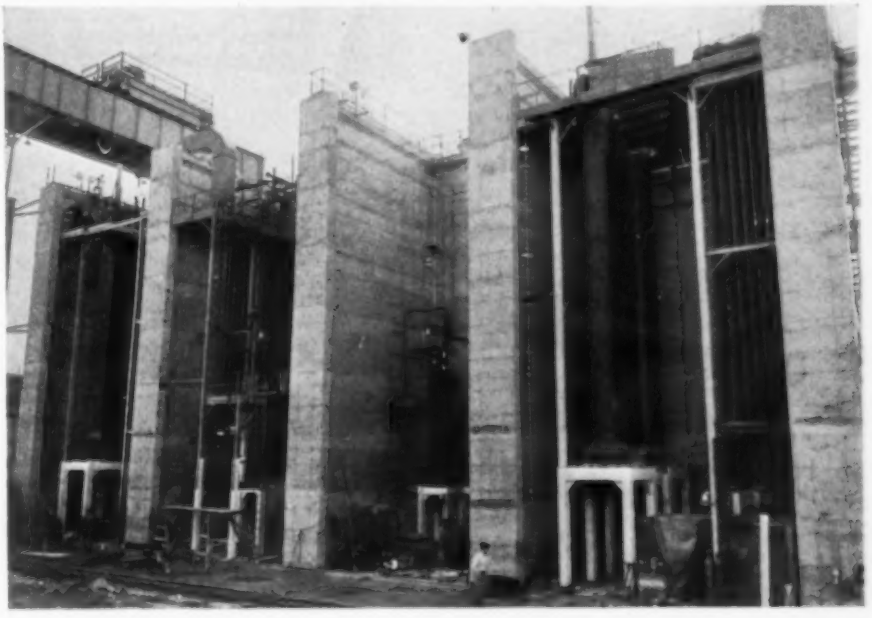
The first of the new units—the hydrogenation demonstration plant—now is ready for operation. Production capacity is from 200 to 300 bbl daily, depending on the coal and catalyst used. Built under contract with the Bechtel Corporation of California, at a cost of $10,000,000, this plant was designed for pressures up to 10,300 psi in two major operations: (1) liquid-phase hydrogenation, which accomplishes liquefaction of the coal; and (2) vapor-phase hydrogenation, which converts the liquefied coal to gasoline and by-products. Chemically, crude petroleum contains more than twice as much hydrogen as does coal. Thus, to convert coal to finished gasoline by this process, hydrogen is added to the coal catalytically under high pressures and high temperatures.

A public "open house" inspection of the plants is scheduled for Friday, May 6, to open a three-day series of events. On Saturday, May 7, industry and government people interested in synthetic fuels development will attend a late afternoon briefing conference at the Statler Hotel in St. Louis and an informal dinner there that evening.

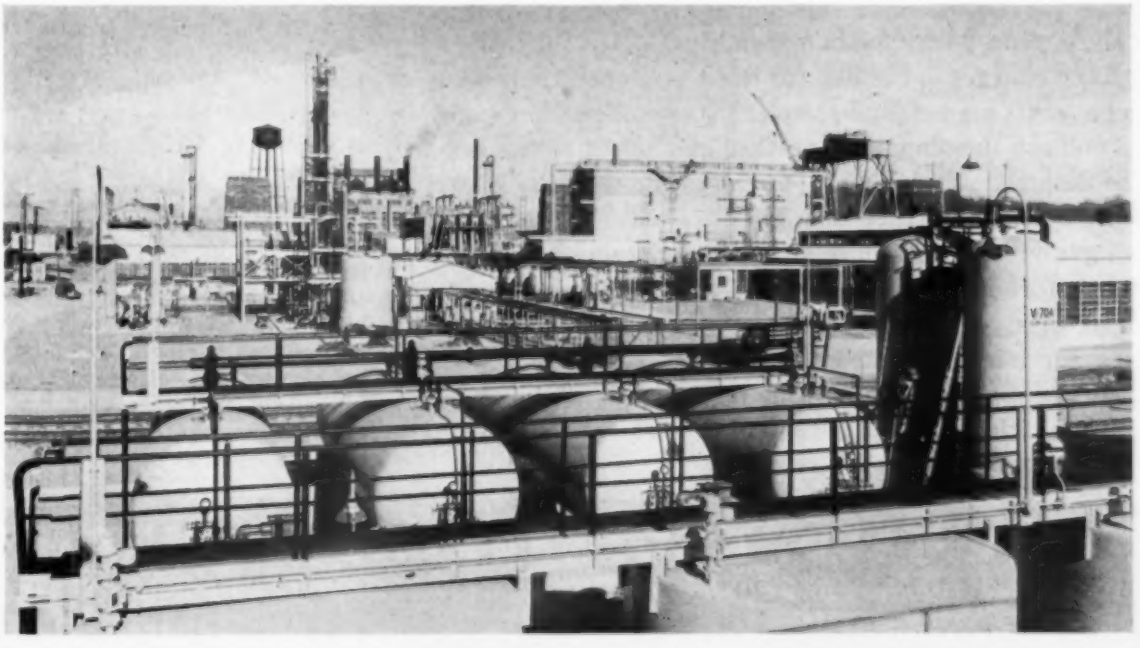
The actual dedication ceremonies will take place at the site of the plants on the afternoon of the VE-Day anniversary, Sunday, May 8. Prominent speakers will appear on both the dinner and dedication programs.

Initially, the plant will process western coals, which lend themselves well to hydrogenation. After the operating difficulties have been ironed out, typical coals from other sections of the country will be tested.

The second of the Bureau's new units—the gas synthesis demonstration plant—is scheduled for completion later this year. This plant will gasify pulverized coal with oxygen and superheated steam and then convert the resulting synthesis gas—a mixture of carbon monoxide and hydrogen—to liquid fuels by the indirect Fischer-Tropsch process.



Coal is converted to oil under high pressure in these 45-ft forged-steel cylinders each 50-in. diameter



General view of coal hydrogenation demonstration plant of the Bureau of Mines

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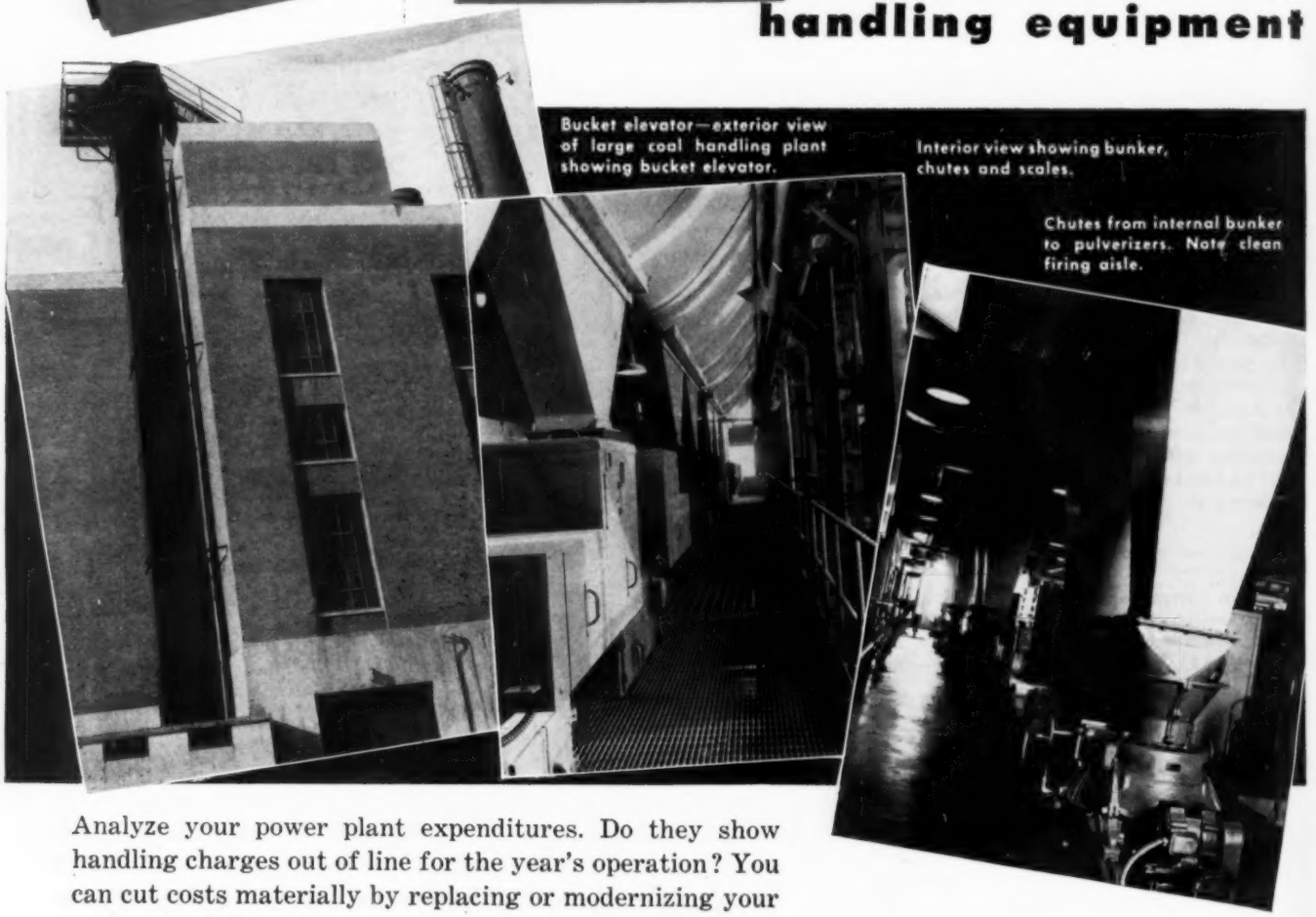
in your plant...

with FAIRFIELD coal and ash handling equipment



Bucket elevator—exterior view of large coal handling plant showing bucket elevator.

Interior view showing bunker, chutes and scales.

Chutes from internal bunker to pulverizers. Note clean firing aisle.

Analyze your power plant expenditures. Do they show handling charges out of line for the year's operation? You can cut costs materially by replacing or modernizing your coal and ash handling system. Coal and ash handling systems designed and built by Fairfield represent the latest in modern handling methods. They are labor-saving, cost-saving and will introduce a cleanliness and efficiency never before known in your boiler house. A Fairfield engineer, with years of practical experience, will gladly talk over your handling problems with you. Write today for his services or a catalog showing new Fairfield equipment and installations. No obligation, of course.

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complete coal and ash handling systems, with silo or bunker storage; bucket elevators; skip hoists; conveyors of all types; crushers; feeders; weigh larries; track hoppers, etc.—also complete glass batch plants and other bulk material handling equipment.

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A.S.M.E. to Meet at New London

THE program for the Spring Meeting of the American Society of Mechanical Engineers to be held at the Mohican Hotel, New London, Conn., on May 2–4, has been announced and includes a number of papers on power and related subjects. Among these are the following:

At the first Power Session on Monday morning there will be two papers—one on "The English Station," at New Haven, by R. L. Anthony, John O. Mullen, C. A. Molsberry and E. H. Walton; and the other on "Modern Mercury Unit Power Plant Design," by H. N. Hackett and Dwight Douglass.

The second Power Session on Monday afternoon will be devoted to the subject of "Marine Fouling." There will be papers on "Fundamentals of Marine Fouling," by W. F. Clapp; "Project Study for the Mitigation of Marine Growth," by Ivan A. Patten; "Marine Fouling in Sea Water Conduits and Cooling Water Systems," by H. E. White; and "Marine Fouling by Temperature Control," by W. L. Chadwick and F. S. Clark.

The third Power Session, on Tuesday morning will contain a paper by A. R. C. Markl and H. H. George on "Fatigue Tests of Flanged Assemblies," and another on "Submarine Operation and Repair," by Donald Bear, U.S.N.

This will be followed by a Power Division Luncheon at which I. E. Moultrop will talk on "Fifty Years of Steam Power Stations."

A Fuels Session on Tuesday afternoon has three scheduled papers, namely, "Stoker Firing Today and Tomorrow," by J. S. Bennett and F. C. Messaros; "Furnace Performance with Overfire Jets," by W. S. Major; and "Cause and Prevention of Slag on Heating Surfaces of High-Pressure Boilers," by E. F. Walsh.

There will be other sessions on materials handling, production engineering, management, industrial instruments, machine design, heat transfer, metals engineering, safety, process industries, and a forum on education. At the Monday luncheon Harry R. Westcott of Westcott & Mapes, consulting engineers, will talk on "The Engineer's Part in the Prosperity of Tomorrow." One on Tuesday will have two speakers, F. A. Magoun and R. C. Nyman, whose subject will be "The Engineer and His Philosophy." A third, on Wednesday, will have as the topic "The Problems and Significance of Our Alliance with Socialist Europe," the speaker being Frederick S. Blackall, Jr.

Inspection trips are scheduled to the United Aircraft Corporation at East Hartford, the Mystic Marine Museum, the U. S. Naval Base at New London and the Montville Power Station of the Connecticut Light & Power Company, the last mentioned being scheduled for Wednesday morning.

The usual banquet will be held on Tuesday evening with Rear Admiral James Fife, commander of the Submarine Force, U. S. Atlantic Fleet, as the principal speaker whose subject will be "The Road to Peace." There will also be an address by James M. Todd, president A.S.M.E.

Civil Service Openings for Engineers

The U. S. Civil Service Commission has been accepting applications for several months for engineer positions, but sufficient eligibles have not yet been obtained to fill existing vacancies. The Commission wishes to bring these examinations to the attention of qualified persons who have not yet applied. The jobs are located in various Federal agencies in Washington, D. C., and vicinity, and pay entrance salaries ranging from $2974 to $5905 a year.

No written test is required for any of the positions. To qualify, applicants must have had education or experience in engineering or a combination of such education and experience. For positions paying $3397 and higher, professional engineering experience is also required. The maximum age limit for jobs at $2974 is 35 years; for other jobs, 62 years.

Announcements and application forms may be obtained from the U. S. Civil Service Commission, Washington 25, D. C. Applications for the higher-paying positions will be accepted until June 30, 1949.

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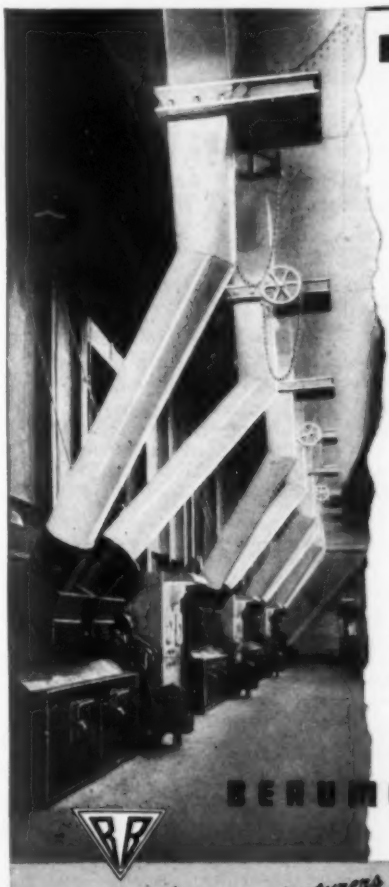

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Many leading plants throughout the country are finding it economical and time-saving to install Beaumont trouble-free type gates such as those pictured at left. Follow the leaders and do the same. These gates are made in sizes from 14" to 30". Request complete information.

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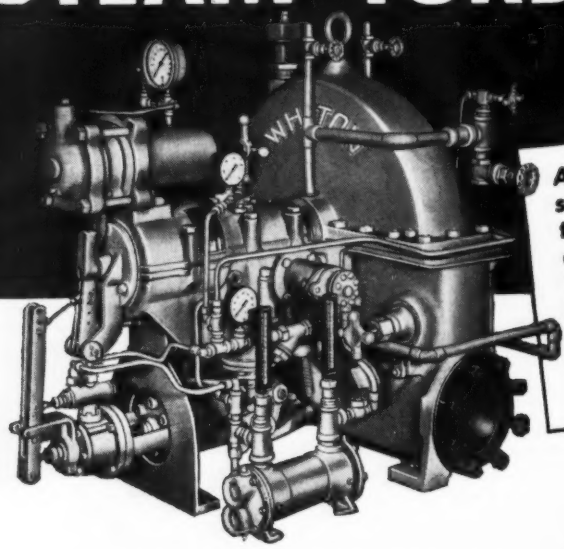
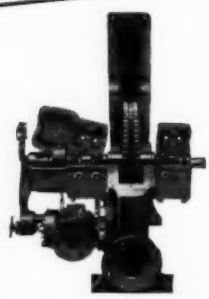


Available in single stage types up to approximately 1200 HP rating. Center supported frames are available when required.



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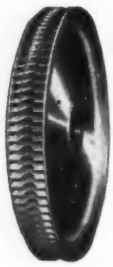
Inlet and exhaust connections are located in lower half of casing which is horizontally split to allow easy access to all internal parts. Rotating unit including governor head may be removed without disturbing alignment of the unit.



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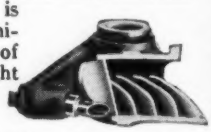

Ejector Shaft Packings assist in eliminating steam leakage to the oil reservoirs. They require a minimum of maintenance.

Whiton Turbine Bearings are horizontally split for easy removal. They consist of bronze or semi-steel shells with babbitt liners, precision fitted at the factory.

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Some Observations on Power

Speaking at the recent ACI Fuel Engineering Conference in Detroit, **Walker L. Cisler**, executive vice president of The Detroit Edison Company, estimated that private utility power systems will make an average annual investment of $1^1/_2$ billion dollars in expansion programs in the next five years. Pointing out that the capacity of our existing electric utility systems amounts to 56,500,000 kw, with an additional 13,000,000 kw installed in industrial plants, railway and other stationary generating plants in the United States, this total of nearly 70,000,000 kw, he said, "is one of our most formidable resources for both peacetime pursuits and national defense."

Referring to the ever-increasing efficiency in the utilization of coal, Mr. Cisler recalled that in 1914 a ton of coal produced 525 kwhr of electricity; in 1946, 1550 kwhr; and he predicted that the most efficient plants now building or projected will individually attain a production of 2400 kwhr per ton of coal. He was of the opinion that there is need to maintain an economic and coordinated balance between fuel-generated and hydraulic-generated capacity in order to insure adequate power at low cost, particularly during dry weather, as most of the difficulty in power shortage has been in areas served by hydro power without adequate fuel-generated standby. "Hydroelectric developments," he said, "are beautiful; they make nice lakes, but their real cost should be made known and properly apportioned." Coal will continue to account for about two-thirds of new fuel burning capacity.

Commenting on atomic power, Mr. Cisler was of the opinion that the so-called atomic pile will not be furnishing heat for the generation of appreciable quantities of electricity for a long time. The work now under way by the Atomic Energy Commission should yield results in time, but these results are not in immediate prospect because of many factors.

Coal Conference at Purdue

On May 10 and 11 an industrial coal conference will be held in the Memorial Union Building at Purdue University, Lafayette, Ind. The first, or Tuesday morning, session will be devoted to a discussion of cyclone burners. That afternoon there will be one session on combustion controls of the off-and-on, positioning, and metering types, and another on overfire air for spreader stokers.

At the morning session of the second day, operation of small boiler plants, particularly coal and ash handling, and operation of fuel-burning equipment will be discussed. The afternoon session will deal with operational problems in connection with chain-grate and spreader stokers, also pulverized coal equipment.

While there will be some papers on these subjects, the plan is to evoke as much discussion from the floor as possible, and representatives of equipment manufacturers are being invited to present their views and to answer questions.

A diversion from the technical aspects of the program will be a dinner meeting at

which the speaker will talk on a subject of international interest. There will also be specialty numbers from the Purdue musical organizations.

Pipe Size vs. Temperature Drop

Regardless of the thickness of insulation used, a surprisingly large loss of steam superheat may occur if the diameter of the steam line is too large for the desired steam flow conditions, according to the Magnesia Insulation Manufacturers Association.

Such a case occurred recently in a plant where an outdoor line, 6 in. in diameter and 925 ft long, with an ambient air temperature of 80 F, was used to transmit superheated steam at 250 psi and 600 F. The line was insulated with $2^{5}/_{16}$-in. thick 85 per cent magnesia pipe insulation. However, the steam temperature at the end of the line was only 450 F.

An analysis indicated that the steam velocity in the line was only a little over 1300 ft per minute, whereas it should have been between 6000 and 10000 ft per minute. The result was that, due to the relatively large size of the pipe and the relatively low steam velocity, there was a large drop in superheat. The investigation showed also that simply increasing the amount of insulation would have no appreciable effect on the extent of superheat loss. The recommendation was that it would be cheaper and more satisfactory to replace the 6-in. line with a $1^{1}/_{2}$ or 2-in. pipe, insulated with 3-in. thick 85 per cent magnesia.

Power Figures for February

Reporting under date of March 30, the Federal Power Commission gave the February production of electric utilities in the United States as slightly under 23 billion kilowatthours, which was the highest February output on record and 3.6 per cent over the corresponding month of last year. However, there was a decrease of 9.6 per cent in the coal consumption over 1948, which was probably due to increases of 8.9 per cent in the amount of gas used and 16.2 per cent in the quantity of oil burned. Also, the production of electricity from water power increased from 28.7 to 31.7 per cent.

There was a net increase of 543,000 kw in installed capacity of electric generating stations during February of this year, bringing the total up to 77,315,777 kw.

Industrial production, including generation by railway stationary plants, was a little less than $4^{1}/_{2}$ billion kilowatthours, an increase of 4.6 per cent over that of the same month last year, and the total installed capacity of such plants is reported as 13,164,590 kw.

Thus the combined utility and industrial output was 3.8 per cent above the same month last year and for the 12-month period ending February 28, 1949, the combined output was $8^{1}/_{2}$ per cent over the corresponding period a year earlier.

GET THE DRAFT GAGE THAT

fits your needs

• There's no sense in buying a large, expensive draft gage when a smaller one will serve quite as well, or even better; nor is it necessary to make one gage handle all drafts.

• Hays offers a comprehensive line of draft gages to meet all needs—from the small "B" gage measuring 5 by 7 inches, to the Series FOT—12 by 14 inches with a scale 10¼ inches wide.

• Vital part in all these gages is the famous Hays slack diaphragm measuring unit for pressures to 120 in. water. Above 120 in. water Bourdon Tubes are used.

• Once it's installed, you can forget your Hays Gage. It is designed and constructed to function accurately through many years of dependable service.

• A "must" for every data file is the interesting booklet: "DRAFT—What, Where, How, Why." Glad to send it on request.

Series F O T
Size—14" x 12"

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Size—12¼" X 9½"

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Size—12½" X 7"

Series B
Size—7" X 5"

Slack Diaphragm
Measuring Unit

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Since 1901
COMBUSTION & INDUSTRIAL INSTRUMENTS & CONTROL
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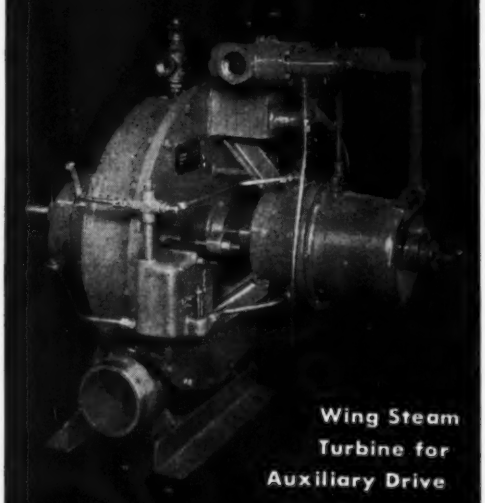
AUXILIARY TURBINES

Wing All-Steel Welded Vertical Turbine for Pump Drive

Wing Steam Turbines have been a dependable source of power in industrial and marine applications for over a third of a century. During that time these sturdy, dependable prime movers have been giving satisfactory service in thousands of industrial and marine installations under the most exacting conditions of service.

Wing turbines today are available for pressures up to 600 psi. and temperatures up to 750° F.

Write for turbine bulletin or for specific details.



Wing Steam Turbine for Auxiliary Drive

L. J. Wing Mfg. Co.
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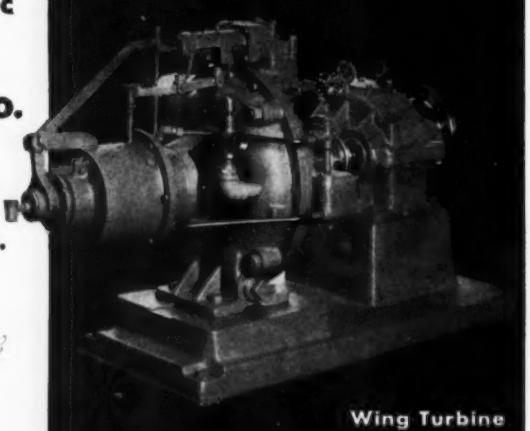

Wing Turbine and Gear Combination on common pedestal base

Personals

A. D. Colvin was recently elected president of the Connecticut Power Co., succeeding Samuel Ferguson who became chairman of the board. Mr. Colvin had been executive vice president of the Company since 1929.

Charles E. Kaufman has been named assistant director of research at Hall Laboratories, Pittsburgh. He has been with that organization since 1936, at which time he received his chemical engineering degree from the University of Cincinnati.

E. M. Greenstreet, formerly an engineer with the Packard Motor Car Co., has been appointed to the staff of Battelle Memorial Institute, Columbus, O., where he will be associated with research in fuels and combustion.

T. R. Hardin has been made chief engineer of the boiler division of The Hartford Steam Boiler Inspection and Insurance Co., succeeding the late W. D. Halsey.

Carl A. Marshall has been appointed director of the Fairmont Coal Bureau, New York, relieving E. C. Payne, who served as acting director since the resignation of Julian E. Tobey early last fall. Following a number of years with Consolidation Coal Co., Mr. Marshall entered military service in 1942, and was later assigned to the European Theater as solid fuels officer.

Ollison Craig, formerly engineering manager, has been made vice president of Riley Stoker Corp. in charge of research and development.

Edwin Lundgren has been appointed Washington representative of Kuljian Corporation, consulting engineers and constructors. For several years past Mr. Lundgren was mechanical engineer with the Navy Department's Bureau of Yards and Docks.

Business Notes

Cochrane Corporation, Philadelphia, manufacturer of water conditioning equipment and steam specialties, has acquired substantially all of the capital stock of **Liquid Conditioning Corporation,** of Linden, N. J., which manufactures a complete line of equipment for the conditioning of water and other liquids under the trade name "Liquon." Hereafter Liquid Conditioning Corporation will operate as a wholly owned subsidiary of Cochrane and the engineering, sales and technical staffs of the two corporations will augment each other.

Thomas C. Wilson, Inc., Long Island City, N. Y., long established manufacturer of tube-cleaning equipment, has acquired the tube-expander business of **Richard Dudgeon, Inc.,** New York City, which will henceforth devote its entire

efforts to the production of hydraulic machinery. The purchase will expand the Wilson line of equipment to handle both rolling and cleaning of all types of heat-transfer tubing.

Hagan Corporation, Pittsburgh, has named Alfred Watson manager of its Buffalo district office, succeeding Charles A. Randorf who is continuing service with Hagan and other companies in Buffalo as a manufacturers' agent.

Manning, Maxwell & Moore, Inc., Bridgeport, Conn., announces the appointment of John C. Leitch as a Hancock valve specialist covering the southeastern territory with headquarters in Atlanta, Ga.

Dearborn Chemical Co. Ltd., Toronto, has elected H. Neville Potter executive vice president and general manager.

Milwaukee to Have Power Meeting

The Annual Wisconsin Power Conference and Exposition, under sponsorship of the NAPE State Association and Associated Engineers and Supplymen of Wisconsin, will be held at the Schroeder Hotel, Milwaukee, June 3 to 4, inclusive.

The tentative program includes papers on safety in boiler operation, overfire air, economy of fuels, feedwater control, insulation and air pollution. Movies of furnace operation will also be shown.

HANDLE YOUR COAL

for only a few cents a ton-

By installing a Sauerman Scraper System you obtain the most efficient, economical method of storing and reclaiming your coal.

Sauerman Scrapers work effectively on areas of any size and shape, building up a compact pile, layer upon layer. Never any air pockets to encourage spontaneous combustion.

The entire operation of a Sauerman Scraper—storing and reclaiming—can be handled by one man. Machines range from the small 10 ton-per-hour, to large 600 ton-per-hour. A Sauerman Scraper is a permanent, trouble-free investment—maintained and operated at the lowest possible cost.

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Two small Sauerman Power Scrapers handle adjoining stockpiles of coal and coke at aluminum refinery. Cars dump into track hoppers at foot of elevators which lift the fuel to the chutes that form the initial piles. Whether storing or reclaiming, each scraper makes about 40 round trips an hour.

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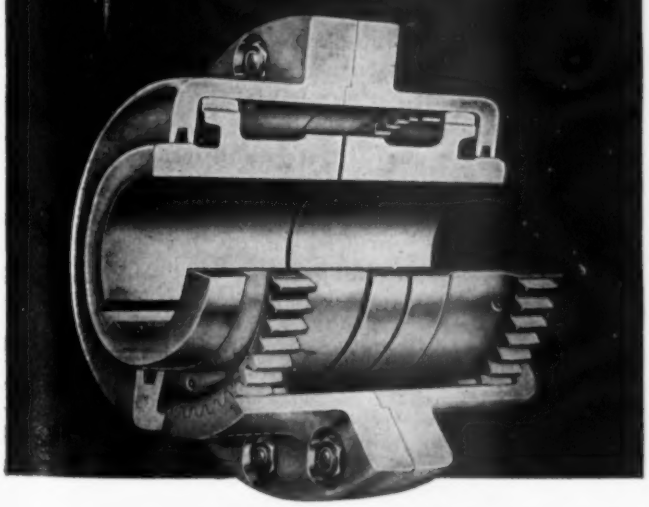

A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

PULSATION A PROBLEM?

Install an **IMO**

With an IMO Pump delivery is not interrupted by the periodic strokes of a piston or the opening and closing of valves and ports. The turning of the rotors in an IMO forces the fluid from suction to discharge in a continuous, uniform flow.

IMO pumps can be furnished for practically any capacity and pressure required for oil, hydraulic-control fluids and other liquids.

Send for Bulletin I-145-V.

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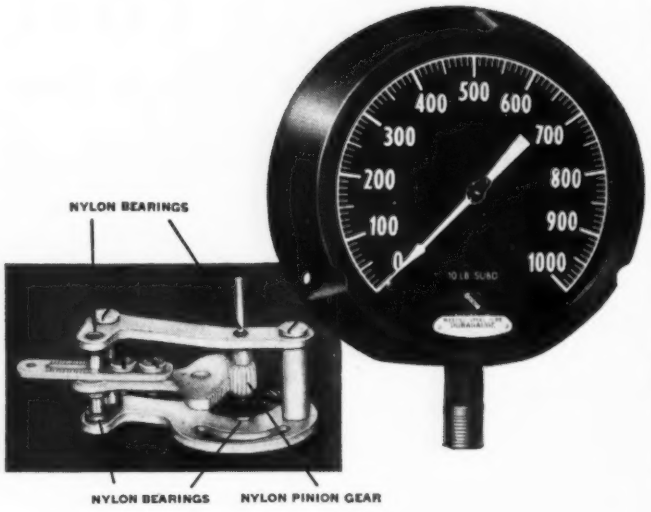

Now–Duragauges with NYLON movements!

A REVOLUTIONARY new development in the construction of Duragauges is the Nylon Movement. Exhaustively field-tested and employing well established engineering principles, this new movement outwears and outperforms any other gauge movement even under the most severe conditions of vibration and pulsation.

Nylon far surpasses the wearing qualities and corrosion resistance of any material heretofore available for pressure gauge movements. It has an extremely low co-efficient of friction, high resistance to shock loading and excellent vibration-absorbing traits.

With this new Nylon Movement are combined all of the features that have made Duragauge the pace-maker of the gauge industry.

When selecting gauges, look for the name ASHCROFT, a leader since 1850.

Stocked and sold by leading Distributors everywhere. When you order gauges, insist on ASHCROFT.

ASHCROFT *Gauges*

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Makers of Ashcroft Gauges, Hancock Valves, Consolidated Safety and Relief Valves and 'American' Industrial Instruments. Builders of 'Shaw-Box' Cranes, 'Budgit' and 'Load Lifter' Hoists and other lifting specialties.

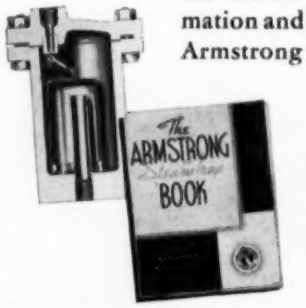
ARMSTRONG *"Power Plant"* STEAM TRAPS

. . . Meet All Requirements for Modern High Pressure, High Temperature Service

ANY engineer responsible for the design or operation of modern, high pressure, high temperature steam plants can safely provide the benefits of completely automatic condensate drainage by specifying Armstrong Forged Steel Steam Traps. Their inherently trouble-free design plus highest quality materials and workmanship assure safety and dependable performance. There is no chance of failure to open when condensate fills the trap and no steam loss under no-load conditions. The extensive line includes traps to meet any pressure, temperature or capacity requirements.

Armstrong Forged Steel Traps are also ideally suited to low and medium pressure service where "all-steel" installations are desired.

Where quality, safety and dependability come first, specify ARMSTRONG, the "standard" in many high pressure plants throughout the world. For more complete information and prices, consult your nearby Armstrong Representative or write:



• SEND FOR the 36-page ARMSTRONG STEAM TRAP BOOK for complete data on sizes, capacities, selection, installation and maintenance of Forged Steel and Cast Semi-Steel Steam Traps.

ARMSTRONG MACHINE WORKS
814 Maple St., Three Rivers, Mich.

NEW EQUIPMENT

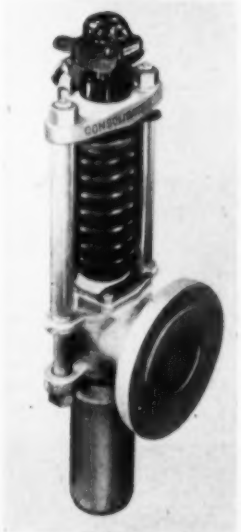
Smoke Density Indicator

The General Electric Co., Schenectady, N. Y., has developed a new smoke density indicator and control to designate industrial smoke density levels and facilitate compliance with smoke abatement ordinances. Consisting of a light source, a phototube holder and an enclosure containing

the required control, and incorporating an indicator calibrated in Ringlemann units, the equipment also contains a magnetic relay which is set to operate when the smoke density reaches a predetermined level. A chart-type recorder may also be used along with the indicator to provide a continuous record of smoke density.

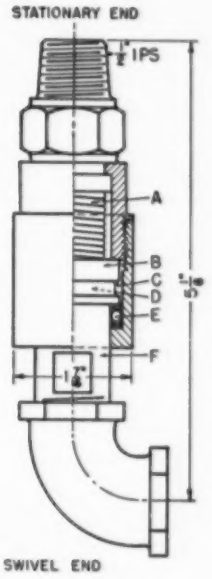
Safety Valve

Manning, Maxwell & Moore, Inc., Bridgeport, Conn., have made available an addition to the Consolidated safety valve line known as the Consolidated "Maxiflow". This valve has been specifically designed to function with a blowdown as low as 1 per cent. Blowdown control consists of a lower ring, an outer ring and a trim ring, and does not require the use of adjustable ports. Thermodisc seat design has also been incorporated and is said to guarantee a degree of tightness not previously obtainable. A removable through bushing providing optimum entrance conditions for steam flow is also provided. This safety valve can be easily disassembled and the spring load can be retained during disassembly.



Swivel Joint

The Seamlex Co., Long Island City, N. Y., has developed a new swivel joint called "Swivlex" which is suitable for 400 psig and 600 F maximum conditions. The



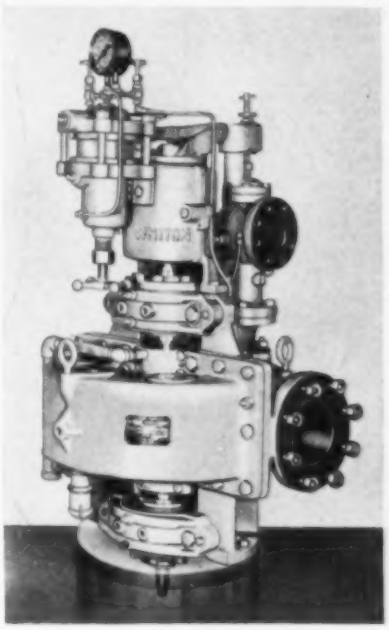
joints are of all-metal construction, having stainless steel bellows which act to keep the metal-to-metal seat under preadjusted pressure to prevent leakage. They find application on hydraulic presses, laundry presses, vulcanizers and mixing machines and are available in standard sizes up to 1 in.

Fuel Oil Treatment for Oil-Fired Furnaces

National Aluminate Corp., Chicago, has announced availability of a new fuel-oil treatment for use in oil-fired locomotives and boiler furnaces. The product, called "Nalco" SR-155, is said to prevent sludge formation in storage tanks, eliminate fouling of fuel oil preheaters, stop gumming at burner tips, and remove soot in the combustion chamber and flues. It is added to the fuel oil in the storage tank and requires no special feeding equipment. Extensive testing in locomotives and power plants indicates that its use can result in substantial time and fuel savings under sludge, gumming or soot conditions.

Vertical Turbine

To meet the demand for vertical steam turbines to drive centrifugal pumps and other vertical units, the Whiton Machine Co., New London, Conn., has designed a unit capable of developing horsepower



ratings up to 90 bhp. The turbine is available in either semi-steel or cast steel to meet a variety of steam requirements. It is equipped with both constant-speed and emergency governors, and pump governors can also be built into the machine.

Unit Heater

The Thermobloc Division of Prat-Daniel Corp., East Port Chester, Conn., has announced the availability of Model 300, direct-fired unit heater. The unit is 7 ft high and 30 in. in diameter and is completely packaged, with only the fuel, electrical and flue connections necessary to place it in operation. Because of its completely automatic features, the unit is ideal as a dryer, for circulating cool air from the floor level to the working level, and as a portable heating unit.

Fact File on Preheat

IN THE LJUNGSTROM, heat is not required to pass *through* the metal and its surface accumulations.

This type of air preheater maintains heat recovery at a *constant level* despite the inevitable surface accumulation of soot and fly ash.

Between cleanings, the surface "as is," acts as an efficient heat storage and transfer medium.

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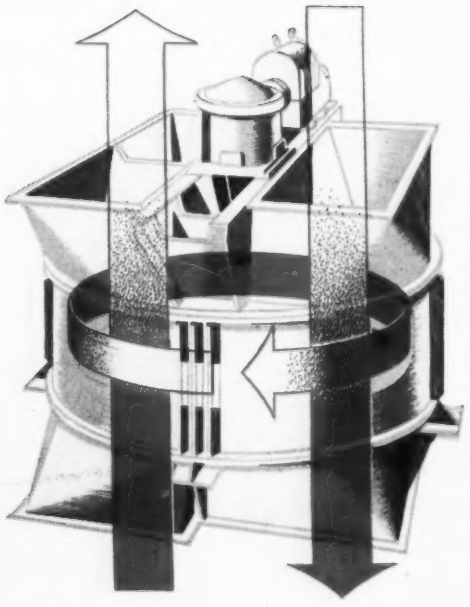

The Ljungstrom Air Preheater is a compact gas-to-air or gas-to-gas heat exchanger, operating on a continuous regenerative counterflow basis. Hundreds of power plants and other special applications confirm its high level of heat recovery and long-term service at low maintenance expense. Write for engineering details to:

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